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ADDRESS OF THE PRESIDENT OF THE MATHEMATICAL AND PHYSICAL SECTION OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

IT is fitting that before entering upon the business of the Section we should pause to take note of the losses which our department of science has recently sustained. The fame of Bertrand, apart from his official position as Secretary of the French Academy of Sciences, was long ago universally established by his classical treatise on the 'Infinitesimal Calculus': it has been of late years sustained by the luminous exposition and searching criticism of his books on the 'Theory of Probability' and 'Thermodynamics' and 'Electricity.' The debt which we owe to that other veteran, G. Wiedemann, both on account of his own researches, which take us back to the modern revival of experimental physics, and for his great and indispensable thesaurus of the science of electricity, cannot easily be overstated. By the death of Sophus Lie, following soon after his return to a chair in his native country Norway, we have lost one of the great constructive mathematicians of the century, who has in various directions fundamentally expanded the methods and conceptions of analysis by reverting to the fountain of direct geometrical intuition. In Italy the death of Beltrami has removed

an investigator whose influence has been equally marked on the theories of transcendental geometry and on the progress of mathematical physics. In our own country we have lost in D. E. Hughes one of the great scientific inventors of the age; while we specially deplore the removal in his early prime, of one who has recently been well known at these meetings, Thomas Preston, whose experimental investigations on the relations between magnetism and light, combined with his great powers of lucid exposition, marked out for him a brilliant future.

Perhaps the most important event of general scientific interest during the past year has been the definite undertaking of the great task of the international coordination of scientific literature; and it may be in some measure in the prolonged conferences that were necessitated by that object that the recently announced international federation of scientific academies has had its origin. In the important task of rendering accessible the stores of scientific knowledge, the British Association, and in particular this Section of it, has played the part of pioneer. Our annual volumes have long been classical, through the splendid reports of progress of the different branches of knowledge that have been from time to time contributed to them by the foremost British men of science; and our work in this direction has received the compliment of successful imitation by the sister Associations on the Continent.

The usual conferences connected with our department of scientific activity have been this year notably augmented by the very successful international congresses of mathematicians and of physicists which met a few weeks ago in Paris. The three volumes of reports on the progress of physical science during the last ten years, for which we are indebted to the initiative of the French Physical Society, will provide an admirable conspectus of the present trend of activity, and form a permanent record for the history of our subject.

Another very powerful auxiliary to progress is now being rapidly provided by the republication, in suitable form and within reasonable time, of the collected works of the masters of our science. We have quite recently received, in a large quarto volume, the mass of most important unpublished work that was left behind him by the late Professor J. C. Adams; the zealous care of Professor Sampson has worked up into order the more purely astronomical part of the volume; while the great undertaking, spread over many years, of the complete determination of the secular change of the magnetic condition of the earth, for which the practical preparations had been set on foot by Gauss himself, has been prepared for the press by Professor W. G. Adams. By the publication of the first volume of Lord Rayleigh's papers a series of memoirs which have formed a main stimulus to the progress of mathematical physics in this country during the past twenty years has become generally accessible. The completed series will form a landmark for the end of the century that may be compared with Young's 'Lectures on Natural Philosophy' for its beginning.

The recent reconstruction of the University of London and the foundation of the University of Birmingham will, it is to be hoped, give greater freedom to the work of our University Colleges. The system of examinations has formed an admirable stimulus to the effective acquisition of that general knowledge which is a necessary part of all education. So long as the examiner recognizes that his function is a responsible and influential one, which is to be taken seriously from the point of view of moulding the teaching in places where external guidance is helpful, test by examination will remain a most valuable means of

extending the area of higher education. Except for workers in rapidly progressive branches of technical science, a broad education seems better adapted to the purposes of life than special training over a narrow range; and it is difficult to see how a reasonably elastic examination test can be considered as a hardship. But the case is changed when preparation for a specialized scientific profession, or mastery of the lines of attack in an unsolved problem, is the object. The general education has then been presumably finished; in expanding departments of knowledge, variety rather than uniformity of training should be the aim, and the genius of a great teacher should be allowed free play without external trammels. It would appear that in this country we have recently been liable to unduly mix up two methods. We have been starting students on the special and lengthy, though very instructive, processes which are known as original research at an age when their time would be more profitably employed in rapidly acquiring a broad basis of knowledge. As a result, we have been extending the examination test from the general knowledge to which it is admirably suited into the specialized activity which is best left to the stimulus of personal interest. Informal contact with competent advisers, themselves imbued with the scientific spirit, who can point the way towards direct appreciation of the works of the masters of the science, is far more effective than detailed instruction at second hand, as regards growing subjects that have not yet taken on an authoritative form of exposition. Fortunately there seems to be now no lack of such teachers to meet the requirements of the technical colleges that are being established throughout the country.

The famous treatise which opened the modern era by treating magnetism and electricity on a scientific basis appeared just 300 years ago. The author, William Gilbert, M.D., of Colchester, passed from the Grammar School of his native town to St. John's College, Cambridge; soon after taking his first degree, in 1560, he became a Fellow of the College, and seems to have remained in residence, and taken part in its affairs, for about ten years. All through his subsequent career, both at Colchester and afterwards at London, where he attained the highest position in his profession, he was an exact and diligent explorer, first of chemical and then of magnetic and electric phenomena. In the words of the historian Hallam, writing in 1839, 'in his Latin treatise on the 'Magnet,' he not only collected all the knowledge which others had possessed, but he became at once the father of experimental philosophy in this island'; and no demur would be raised if Hallam's restriction to this country were removed. Working nearly a century before the time when the astronomical discoveries of Newton had originated the idea of attraction at a distance, he established a complete formulation of the interaction of magnets by what we now call the exploration of their fields of force. His analysis of the facts of magnetic influence, and incidentally of the points in which it differs from electric influence, is virtually the one which Faraday reintroduced. A cardinal advance was achieved, at a time when the Copernican Astronomy had still largely to make its way by assigning the behavior of the compass and the dip needle to the fact that the earth itself is a great magnet, by whose field of influence they are controlled. His book passed through many editions on the Continent within forty years; it won the high praise of Galileo. Gilbert has been called 'the father of modern electricity' by Priestley, and 'the Galileo of magnetism' by Poggendorff.

When the British Association last met at Bradford in 1873, the modern theory which largely reverts to Gilbert's way of formula-

tion, and refers electric and magnetic phenomena to the activity of the æther instead of attractions at a distance, was of recent growth; it had received its classical exposition only two years before by the publication of Clerk Maxwell's treatise. The new doctrine was already widely received in England on its own independent merits. On the Continent it was engaging the strenuous attention of Helmholtz, whose series of memoirs, deeply probing the new ideas in their relation to the prevalent and fairly successful theories of direct action across space, had begun to appear in 1870. During many years the search for crucial experiments that would go beyond the results equally explained by both views, met with small success; it was not until 1887 that Hertz, by the discovery of the æthereal radiation of long wave-length emitted from electric oscillators, verified the hypothesis of Faraday and Maxwell and initiated a new era in the practical development of physical science. The experimental field thus opened up was soon fully occupied both in this country and abroad; and the borderland between the sciences of optics and electricity is now being rapidly explored. The extension of experimental knowledge was simultaneous with increased attention to directness of explanation; the expositions of Heaviside and Hertz and other writers fixed attention in a manner already briefly exemplified by Maxwell himself, on the inherent simplicity of the completed æthereal scheme, when once the theoretical scaffolding employed in its construction and dynamical consolidation is removed; while Poynting's beautiful corollary specifying the path of the transmission of energy through the æther has brought the theory into simple relations with the applications of electrodynamics.

Equally striking has been the great mastery obtained during the last twenty years over the practical manipulation of electric power. The installation of electric wires as the nerves connecting different regions of the earth had attained the rank of accomplished fact so long ago as 1857, when the first Atlantic cable was laid. It was largely the theoretical and practical difficulties, many of them unforeseen, encountered in carrying that great undertaking to a successful issue, that necessitated the elaboration by Lord Kelvin and his coadjutors, of convenient methods and instruments for the exact measurement of electric quantities, and thus prepared the foundation for the more recent practical developments in other directions. On the other hand, the methods of theoretical explanation have been in turn improved and simplified through the new ways of considering the phenomena which have been evolved in the course of practical advances on a large scale, such as the improvement of dynamo armatures, the conception and utilization of magnetic circuits, and the transmission of power by alternating currents. In our time the relations of civilized life have been already perhaps more profoundly altered than ever before, owing to the establishment of practically instantaneous electric communication between all parts of the world. The employment of the same subtle agency is now rapidly superseding the artificial reciprocating engines and other contrivances for the manipulation of mechanical power that were introduced with the employment of steam. The possibilities of transmitting power to great distances at enormous tension, and therefore with very slight waste, along lines merely suspended in the air, are being practically realized; and the advantages thence derived are increased many fold by the almost automatic manner in which the electric power can be transformed into mechanical rotation at the very point where it is desired to apply it. The energy is transmitted at such lightning speed that at a given instant only an exceedingly minute

portion of it is in actual transit. When the tension of the alternations is high, the amount of electricity that has to oscillate backwards and forwards on the guiding wires is proportionately diminished, and the frictional waste reduced. At the terminals the direct transmission from one armature of the motor to the other, across the intervening empty space, at once takes us beyond the province of the pushing and rubbing contacts that are unavoidable in mechanical transmission; while the perfect symmetry and reversibility of the arrangement by which power is delivered from a rotatory alternator at one end, guided by the wires to another place many miles away, where it is absorbed by another alternator with precise reversal of the initial stages, makes this process of distribution of energy resemble the automatic operations of nature rather than the imperfect material connections previously in use. We are here dealing primarily with the flawless continuous medium which is the transmitter of radiant energy across the celestial spaces; the part played by the coarsely constituted material conductor is only that of a more or less imperfect guide which directs the current of æthereal energy. The wonderful nature of this theoretically perfect, though of course practically only approximate, method of abolishing limitations of locality with regard to mechanical power is not diminished by the circumstance that its principle must have been in some manner present to the mind of the first person who fully realized the character of the reversibility of a gramme armature.

In theoretical knowledge a new domain, to which the theory as expounded twenty years ago had little to say, has recently been acquired through the experimental scrutiny of the electric discharge in rarefied gaseous media. The very varied electric phenomena of vacuum tubes, whose electrolytic character was first practically established by Schuster, have been largely reduced to order through the employment of the high exhaustions introduced and first utilized by Crookes. Their study under these circumstances, in which the material molecules are so sparsely distributed as but rarely to interfere with each other, has conduced to enlarged knowledge and verification of the fundamental relations in which the individual molecules stand to all electric phenomena, culminating recently in the actual determination, by J. J. Thomson and others following in his track, of the masses and velocities of the particles that carry the electric discharge across the exhausted space. The recent investigations of the circumstances of the electric dissociation produced in the atmosphere and in other gases by ultra-violet light, the Röntgen radiation, and other agencies, constitute one of the most striking developments in experimental molecular physics since Graham determined the molecular relations of gaseous diffusion and transpiration more than half a century ago. This advance in experimental knowledge of molecular phenomena, assisted by the discovery of the precise and rational effect of magnetism on the spectrum, has brought into prominence a modification or rather development of Maxwell's exposition of electric theory, which was dictated primarily by the requirements of the abstract theory itself; the atoms or ions are now definitely introduced as the carriers of those electric charges which interact across the æther, and so produce the electric fields whose transformations were the main subject of the original theory.

We are thus inevitably led, in electric and æthereal theory, as in the chemistry and dynamics of the gaseous state which is the department of abstract physics next in order of simplicity, to the consideration of the individual molecules of matter. The theoretical problems which

had come clearly into view a quarter of a century ago, under Maxwell's lead, whether in the exact dynamical relations of æthereal transmission or in the more fortuitous domain of the statistics of interacting molecules, are those around which attention is still mainly concentrated; but as the result of the progress in each, they are now tending towards consolidation into one subject. I propose—leaving further review of the scientific aspect of the recent enormous development of the applications of physical science for hands more competent to deal with the practical side of that subject—to offer some remarks on the scope and validity of this molecular order of ideas, to which the trend of physical explanation and development is now setting in so pronounced a manner.

If it is necessary to offer an apology for detaining the attention of the Section on so abstract a topic, I can plead its intrinsic philosophical importance. The hesitation so long felt on the Continent in regard to discarding the highly developed theories which analyzed all physical actions into direct attractions between the separate elements of the bodies concerned, in favor of a new method in which our ideas are carried into regions deeper than the phenomena, has now given place to eager discussion of the potentialities of the new standpoint. There has even appeared a disposition to consider that the Newtonian dynamical principles, which have formed the basis of physical explanation for nearly two centuries, must be replaced in these deeper subjects by a method of direct description of the mere course of phenomena, apart from any attempt to establish causal relations; the initiation of this method being traced, like that of the Newtonian dynamics itself, to this country. The question has arisen as to how far the new methods of æthereal physics are to be considered as an independent departure, how far they form the natural development of existing dynamical science. In England, whence the innovation came, it is the more conservative position that has all along been occupied. Maxwell was himself trained in the school of physics established in this country by Sir George Stokes and Lord Kelvin, in which the dominating idea has been that of the strictly dynamical foundation of all physical action. Although the pupil's imagination bridged over dynamical chasms, across which the master was not always able to follow, yet the most striking feature of Maxwell's scheme was still the dynamical framework into which it was built. The more advanced reformers have now thrown overboard the apparatus of potential functions which Maxwell found necessary for the dynamical consolidation of his theory, retaining only the final result as a verified descriptive basis for the phenomena. In this way all difficulties relating to dynamical development and indeed consistency are avoided, but the question remains as to how much is thereby lost. In practical electromagnetics the transmission of power is now the most prominent phenomenon; if formal dynamics is put aside in the general theory, its guidance must here be replaced by some more empirical and tentative method of describing the course of transmission and transformation of mechanical energy in the system.

The direct recognition in some form, either explicitly or tacitly, of the part played by the æther has become indispensable to the development and exposition of general physics ever since the discoveries of Hertz left no further room for doubt that this physical scheme of Maxwell was not merely a brilliant speculation, but constituted, in spite of outstanding gaps and difficulties, a real formulation of the underlying unity in physical dynamics. The domain of abstract physics is in fact roughly divisible into two regions. In one of them we are

mainly concerned with interactions between one portion of matter and another portion occupying a different position in space; such interactions have very uniform and comparatively simple relations; and the reason is traceable to the simple and uniform constitution of the intervening medium in which they have their seat. The other province is that in which the distribution of the material molecules comes into account. Setting aside the ordinary dynamics of matter in bulk, which is founded on the uniformity of the properties of the bodies concerned and their experimental determination, we must assign to this region all phenomena which are concerned with the uncoordinated motions of the molecules, including the range of thermal and in part of radiant actions; the only possible basis for detailed theory is the statistical dynamics of the distribution of the molecules. The far more deep-seated and mysterious processes which are involved in changes in the constitution of the individual molecules themselves are mainly outside the province of physics, which is competent to reason only about permanent material systems; they must be left to the sciences of chemistry and physiology. Yet the chemist proclaims that he can determine only the results of his reactions and the physical conditions under which they occur; the character of the bonds which hold atoms in their chemical combinations is at present unknown, although a large domain of very precise knowledge relating, in some diagrammatic manner, to the topography of the more complex molecules has been attained. The vast structure which chemical science has in this way raised on the narrow foundation of the atomic theory is perhaps the most wonderful existing illustration both of the rationality of natural processes and of the analytical powers of the human mind. In a word, the complication of the material world is referable to the vast range of structure and of states of aggregation in the material atoms; while the possibility of a science of physics is largely due to the simplicity of constitution of the universal medium through which the individual atoms interact on each other.

The reference of the uniformity in the interactions at a distance between material bodies to the part played by the æther is a step towards the elimination of extraneous and random hypotheses about laws of attraction between atoms. It also places that medium on a different basis from matter, in that its mode of activity is simple and regular, whereas intimate material interactions must be of illimitable complexity. This gives strong ground for the view that we should not be tempted towards explaining the simple group of relations which have been found to define the activity of the æther, by treating them as mechanical consequences of concealed structure in that medium; we should rather rest satisfied with having attained to their exact dynamical correlation, just as geometry explores or correlates, without explaining, the descriptive and metric properties of space. On the other hand, a view is upheld which considers the pressures and thrusts of the engineer, and the strains and stresses in the material structures by which he transmits them from one place to another, to be the archetype of the processes by which all mechanical effect is transmitted in nature. This doctrine implies an expectation that we may ultimately discover something analogous to structure in the celestial spaces, by means of which the transmission of physical effect will be brought into line with the transmission of mechanical effect by material frame work.

At a time when the only definitely ascertained function of the æther was the undulatory propagation of radiant energy across space, Lord Kelvin pointed out that, by reason of the very great velocity of prop-

agation, the density of the radiant energy in the medium at any place must be extremely small in comparison with the amount of energy that is transmitted in a second of time: this easily led him to the very striking conclusion that, on the hypothesis that the æther is like material elastic media, it is not necessary to assume its density to be more than 10^{-18} of that of water, or its optical rigidity to be more than ten 10^{-8} of that of steel or glass. Thus far the æther would be merely an impalpable material atmosphere for the transference of energy by radiation, at extremely small densities but with very great speed, while ordinary matter would be the seat of practically all this energy. But this way of explaining the absence of sensible influence of the æther on the phenomena of material dynamics lost much of its basis as soon as it was recognized that the same medium must be the receptacle of very high densities of energy in the electric fields around currents and magnets.* The other mode of explanation is to consider the æther to be of the very essence of all physical actions, and to correlate the absence of obvious mechanical evidence of its intervention with its regularity and universality.

On this plan of making the æther the essential factor is the transformation of energy as well as its transmission across space, the material atom must be some kind of permanent nucleus that retains around itself an æthereal field of physical influence, such as, for example, a field of strain. We can recognize the atom only through its interactions with other atoms that are so far away from it as to be practically independent systems; thus our direct knowledge of the atom will be confined to this field of force which belongs to it. Just as the exploration of the distant field of magnetic influence of a steel magnet, itself concealed from view, cannot tell us anything about the magnet except the amount and direction of its moment, so a practically complete knowledge of the field of physical influence of an atom might be expressible in terms of the numerical values of a limited number of physical moments associated with it, without any revelation as to its essential structure or constitution being involved. This will at any rate be the case for ultimate atoms if, as is most likely, the distances at which they are kept apart are large compared with the diameters of the atomic nuclei; it in fact forms our only chance for penetrating to definite dynamical views of molecular structure. So long as we cannot isolate a single molecule, but must deal observationally with an innumerable distribution of them, even this kind of knowledge will be largely confined to average values. But the last half-century has witnessed the successful application of a new instrument of research, which has removed in various directions the limitations that had previously been placed on the knowledge to which it was possible for human effort to look forward. The spectroscope has created a new astronomy by revealing the constitutions and the unseen internal motions of the stars. Its power lies in the fact that it does take hold of the internal relations of the individual molecule of matter, and provides a very definite and detailed, though far from complete, analysis of the vibratory motions

* We can here only allude to Lord Kelvin's recent most interesting mechanical illustrations of a solid æther interacting with material molecules and with itself by attraction at a distance: unlike the generalized dynamical methods expounded in the text, which can leave the intimate structure of the material molecule outside the problem, a definite working constitution is there assigned to the molecular nucleus. It is pointed out in a continuation that is to appear in the *Philosophical Magazine* for September, that a density of æther of the order of only 10^{-9}, which would not appreciably affect the inertia of matter, would involve rigidity comparable with that of steel, and thus permit transmission of magnetic forces by stress; this solid æther is, however, as usual, taken to be freely permeable to the molecules of matter.

that are going on in it; these vibrations being in their normal state characteristic of its dynamical constitution, and in their deviations from the normal giving indications of the velocity of its movement and the physical state of its environment. Maxwell long ago laid emphasis on the fact that a physical atomic theory is not competent even to contemplate the vast mass of potentialities and correlations of the past and the future, that biological theory has to consider as latent in a single organic germ containing at most only a few million molecules. On our present view we can accept his position that the properties of such a body cannot be those of a 'purely material system,' provided, however, we restrict this phrase to apply to physical properties as here defined. But an exhaustive discovery of the intimate nature of the atom is beyond the scope of physics; questions as to whether it must not necessarily involve in itself some image of the complexity of the organic structures of which it can form a correlated part must remain a subject of speculation outside the domain of that science. It might be held that this conception of discrete atoms and continuous æther really stands, like those of space and time, in intimate relation with our modes of mental apprehension, into which any consistent picture of the external world must of necessity be fitted. In any case it would involve abandonment of all the successful traditions of our subject if we ceased to hold that our analysis can be formulated in a consistent and complete manner, so far as it goes, without being necessarily an exhaustive account of phenomena that are beyond our range of experiment. Such phenomena may be more closely defined as those connected with the processes of intimate combination of the molecules: they include the activities of organic beings which all seem to depend on change of molecular structure.

If, then, we have so small a hold on the intimate nature of matter, it will appear all the more striking that physicists have been able precisely to divine the mode of operation of the intangible æther, and to some extent explore in it the fields of physical influence of the molecules. On consideration we recognize that this knowledge of fundamental physical interaction has been reached by a comparative process. The mechanism of the propagation of light could never have been studied in the free æther of space alone. It was possible, however, to determine the way in which the characteristics of optical propagation are modified, but not wholly transformed, when it takes place in a transparent material body instead of empty space. The change in fact arises on account of the æther being entangled with the network of material molecules; but inasmuch as the length of a single wave of radiation covers thousands of these molecules the wave-motion still remains uniform and does not lose its general type. A wider variation of the experimental conditions has been provided for our examination in the case of those substances in which the phenomenon of double refraction pointed to a change of the æthereal properties which varied in different directions; and minute study of this modification has proved sufficient to guide to a consistent appreciation of the nature of this change, and therefore of the mode of æthereal propagation that is thus altered. In the same way, it was the study and development of the manner in which the laws of electric phenomena in material bodies had been unraveled by Ampère and Faraday, that guided Faraday himself and Maxwell—who were impressed with the view that the æther was at the bottom of it all—in their progress towards an application of similar laws to æther devoid of matter, such as would complete a scheme of continuous action by consist-

ently interconnecting the material bodies and banishing all untraced interaction across empty space. Maxwell in fact chose to finally expound the theory by ascribing to the æther of free space a dielectric constant and a magnetic constant of the same type as had been found to express the properties of material media, thus extending the seat of the phenomena to all space on the plan of describing the activity of the æther in terms of the ordinary electric ideas. The converse mode of development, starting with the free æther under the directly dynamical form which has been usual in physical optics, and introducing the influence of the material atoms through the electric charges which are involved in their constitution,* was hardly employed by him; in part, perhaps, because, owing to the necessity of correlating his theory with existing electric knowledge and the mode of its expression, he seems never to have reached the stage of moulding it into a completely deductive form.

The dynamics of the æther, in fact the recognition of the existence of an æther, has thus, as a matter of history, been reached through study of the dynamical phenomena of matter. When the dynamics of a material system is worked up to its purest and most general form, it becomes a formulation of the relations between the succession of the configurations and states of motion of the system, the assistance of an independent idea of force not being usually required. We can, however, only attain such a compact statement when the system is self-contained, when its motion is not being dissipated by agencies of frictional type, and when its connections can be directly specified by purely geometrical relations between the co-ordinates, thus excluding such mechanisms as rolling contacts. The course of the system is then in all cases determined by some form or other of a single fundamental property, that any alteration in any small portion of its actual course must produce an increase in the total 'Action' of the motion. It is to be observed that in employing this law of minimum as regards the Action expressed as an integral over the whole time of the motion, we no more introduce the future course as a determining influence on the present state of motion than we do in drawing a straight line from any point in any direction, although the length of the line is the minimum distance between its ends. In drawing the line piece by piece we have to make tentative excursions into the immediate future in order to adjust each element into straightness with the previous element; so in tracing the next stage of the motion of a material system we have similarly to secure that it is not given any such directions as would unduly increase the Action. But whatever views may be held as to the ultimate significance of this principle of action, its importance, not only for mathematical analysis, but as a guide to physical exploration, remains fundamental. When the principles of the dynamics of material systems are refined down to their ultimate common basis, this principle of minimum is what remains. Hertz preferred to express its contents in the form of a principle of straightness of course or path. It will be recognized, on the lines already indicated, that this is another mode of statement of the same fundamental idea; and the general equivalence is worked out by Hertz on the basis of Hamilton's development of the principles of dynamics. The latter mode of statement may be adaptable so as to avoid

* In 1870 Maxwell, while admiring the breadth of the theory of Weber, which is virtually based on atomic charges combined with action at a distance, still regarded it as irreconcilable with his own theory, and left to the future the question as to why 'theories apparently so fundamentally opposed should have so large a field of truth common to both.'—*Scientific Papers*, II., p. 228.

the limitations which restrict the connections of the system, at the expense, however, of introducing new variables; if, indeed, it does not introduce gratuitous complexity for purposes of physics to attempt to do this. However these questions may stand, this principle of straightness or directness of path forms, whenever it applies, the most general and comprehensive formulation of purely dynamical action: it involves in itself the complete course of events. In so far as we are given the algebraic formula for the time-integral which constitutes the Action, expressed in terms of any suitable coordinates, we know implicitly the whole dynamical constitution and history of the system to which it applies. Two systems in which the Action is expressed by the same formula are mathematically identical, are physically precisely correlated, so that they have all dynamical properties in common. When the structure of a dynamical system is largely concealed from view, the safest and most direct way towards an exploration of its essential relations and connections, and in fact towards answering the prior question as to whether it is a purely dynamical system at all, is through this order of ideas. The ultimate test that a system is a dynamical one is not that we shall be able to trace mechanical stresses throughout it, but that its relations can be in some way or other consolidated into accordance with this principle of minimum Action. This definition of a dynamical system in terms of the simple principle of directness of path may conceivably be subject to objection as too wide; it is certainly not too narrow; and it is the conception which has naturally been evolved from two centuries of study of the dynamics of material bodies. Its very great generality may lead to the objection that we might completely formulate the future course of a system in its terms, without having obtained a working familiarity with its details of the kind to which we have become accustomed in the analysis of simple material systems; but our choice is at present between this kind of formulation, which is a real and essential one, and an empirical description of the course of phenomena combined with explanations relating to more or less isolated groups. The list of great names, including Kelvin, Maxwell, Helmholtz, that have been associated with the employment of the principle for the elucidation of the relations of deep-seated dynamical phenomena, is a strong guarantee that we shall do well by making the most of this clue.

Are we then justified in treating the material molecule, so far as revealed by the spectroscope, as a dynamical system coming under this specification? Its intrinsic energy is certainly permanent and not subject to dissipation; otherwise the molecule would gradually fade out of existence. The extreme precision and regularity of detail in the spectrum shows that the vibrations which produce it are exactly synchronous whatever be their amplitude, and in so far resemble the vibrations of small amplitude in material systems. As all indications point to the molecule being a system in a state of intrinsic motion, like a vortex ring, or a stellar system in astronomy, we must consider these radiating vibrations to take place around a steady state of motion which does not itself radiate, not around a state of rest. Now not the least of the advantages possessed by the Action principle, as a foundation for theoretical physics, is the fact that its statement can be adapted to systems involving in their constitution permanent steady motions of this kind, in such a way that only the variable motions superposed on them come into consideration. The possibilities as regards physical correlation of thus introducing permanent motional states as well as permanent structure into the constitution of

our dynamical systems have long been emphasized by Lord Kelvin;* the effective adaptation of abstract dynamics to such systems was made independently by Kelvin and Routh about 1877; the more recent exposition of the theory by Helmholtz has directed general attention to what is undoubtedly the most significant extension of dynamical analysis which has taken place since the time of Lagrange.

Returning to the molecules, it is now verified that the Action principle forms a valid foundation throughout electrodynamics and optics; the introduction of the æther into the system has not affected its application. It is therefore a reasonable hypothesis that the principle forms an allowable foundation for the dynamical analysis of the radiant vibrations in the system formed by a single molecule and surrounding æther; and the knowledge which is now accumulating, both of the orderly grouping of the lines of the spectrum and of the modifications impressed on these lines by a magnetic field or by the density of the matter immediately surrounding the vibrating molecule, can hardly fail to be fruitful for the dynamical analysis of its constitution. But let it be repeated that this analysis would be complete when a formula for the dynamical energy of the molecule is obtained, and would go no deeper. Starting from our definitely limited definition of the nature of a dynamical system, the problem is merely to correlate the observed relations of the periods of vibration in a molecule, when it has come into a steady state as regards constitution and is not under the influence of intimate encounter with other molecules.

It may be recalled incidentally that the generalized Maxwell-Boltzmann principle of the equable distribution of the acquired store of kinetic energy of the molecule, among its various possible independent types of motion, is based directly on the validity of the Action principle for its dynamics. In the demonstrations usually offered the molecule is considered to have no permanent or constitutive energy of internal motion. It can, however, be shown, by use of the generalization aforesaid of the Action principle, that no discrepancy will arise on that account. Such intrinsic kinetic energy virtually adds on to the potential energy of the system; and the remaining or acquired part of the kinetic energy of the molecule may be made the subject of the same train of reasoning as before.

Let us now return to the general question whether our definition of a dynamical system may not be too wide. As a case in point, the single principle of Action has been shown to provide a definite and sufficient basis for electrodynamics; yet when, for example, one armature of an electric motor pulls the other after it without material contact, and so transmits mechanical power, no connection between them is indicated by the principle such as could by virtue of internal stress transmit the pull. The essential feature of the transmission of a pull by stress across a medium is that each element of volume of the medium acts by itself, independently of the other elements. The stress excited in any element depends on the strain or other displacement occurring in that element alone; and the mechanical effect that is transmitted is considered as an extraneous force applied at one place in the medium, and passed on from element to element through these internal pressures and tractions until it reaches another place. We have, however, to consider two atomic electric charges as being themselves some kind of strain configurations in the æther; each of them already involves an atmosphere of

* For a classical exposition see his *Brit. Assoc.* Address of 1884 on 'Steps towards a Kinetic Theory of Matter,' reprinted in 'Popular Lectures and Addresses,' vol i.

strain in the surrounding æther which is part of its essence, and cannot be considered apart from it; each of them essentially pervades the entire space, though on account of its invariable character we consider it as a unit. Thus we appear to be debarred from imagining the æther to act as an elastic connection which is merely the agent of transmission of a pull from the one nucleus to the other, because there are already stresses belonging to and constituting an intrinsic part of the terminal electrons, which are distributed all along the medium. Our action criterion of a dynamical system, in fact, allows us to reason about an electron as a single thing, notwithstanding that its field of energy is spread over the whole medium; it is only in material solid bodies, and in problems in which the actual sphere of physical action of the molecule is small compared with the smallest element of volume that our analysis considers, that the familiar idea of transmission of force by simple stress can apply. Whatever view may ultimately command itself, this question is one that urgently demands decision. A very large amount of effort has been expended by Maxwell, Helmholtz, Heaviside, Hertz and other authorities in the attempt to express the mechanical phenomena of electrical action in terms of a transmitting stress. The analytical results up to a certain point have been promising, most strikingly so at the beginning, when Maxwell established the mathematical validity of the way in which Faraday was accustomed to represent to himself the mechanical interactions across space, in terms of a tension along the lines of force equilibrated by an equal pressure preventing their expansion sideways. According to the views here developed, that ideal is an impossible one; if this could be established to general satisfaction the field of theoretical discussion would be much simplified.

This view that the atom of matter is, so far as regards physical actions, of the nature of a structure in the æther involving an atmosphere of æthereal strain all around it, not a small body which exerts direct actions at a distance on other atoms according to extraneous laws of force, was practically foreign to the eighteenth century, when mathematical physics was modelled on the Newtonian astronomy and dominated by its splendid success. The scheme of material dynamics, as finally compactly systematized by Lagrange, had therefore no direct relation to such a view, although it has proved wide enough to include it. The remark has often been made that it is probably owing to Faraday's mathematical instinct, combined with his want of acquaintance with the existing analysis, that the modern theory of the æther obtained a start from the electric side. Through his teaching and the weight of his authority, the notion of two electric currents exerting their mutual forces by means of an intervening medium, instead of by direct attraction across space, was at an early period firmly grasped in this country. In 1845 Lord Kelvin was already mathematically formulating, with most suggestive success, continuous elastic connections, by whose strain the fields of activity of electric currents or of electric distributions could be illustrated; while the exposition of Maxwell's interconnected scheme, in the earlier form in which it relied on concrete models of the electric action, goes back almost to 1860. Corresponding to the two physical ideals of isolated atoms exerting attraction at a distance, and atoms operating by atmospheres of æthereal strain, there are, as already indicated, two different developments of dynamical theory. The original Newtonian equations of motion determined the course of a system by expressing the rates at which the velocity of each of its small parts or elements is changing. This

method is still fully applicable to those problems of gravitational astronomy in which dynamical explanation was first successful on a grand scale, the planets being treated as point-masses, each subject to the gravitational attraction of the other bodies. But the more recent development of the dynamics of complex systems depends on the fact that analysis has been able to reduce within manageable limits the number of varying quantities whose course is to be explicitly traced, through taking advantage of those internal relations of the parts of the system that are invariable, either geometrically or dynamically. Thus, to take the simplest case, the dynamics of a solid body can be confined to a discussion of its three components of translation and its three components of rotation, instead of the motion of each element of its mass. With the number of independent co-ordinates thus diminished when the initial state of the motion is specified the subsequent course of the complete system can be traced; but the course of the changes in any part of it can only be treated in relation to the motion of the system as a whole. It is just this mode of treatmant of a system as a whole that is the main characteristic of modern physical analysis. The way in which Maxwell analyzed the interactions of a system of linear electric currents, previously treated as if each were made up of small independent pieces or elements, and accumulated the evidence that they formed a single dynamical system, is a trenchant example. The interactions of vortices in fluid form a very similar problem, which is of special note in that the constitution of the system is there completely known in advance, so that the two modes of dynamical exposition can be compared. In this case the older method forms independent equations for the motion of each material element of the fluid, and so requires the introduction of the stress—here the fluid pressure—by which dynamical effect is passed on to it from the surrounding elements: it corresponds to a method of contact action. But Helmholtz opened up new ground in the abstract dynamics of continuous media when he recognized (after Stokes) that, if the distribution of the velocity of spin at those places in the fluid where the motion is vortical be assigned, the motion in every part of the fluid is therein kinematically involved. This, combined with the theorem of Lagrange and Cauchy, that the spin is always confined to the same portions of the fluid, formed a starting-point for his theory of vortices, which showed how the subsequent course of the motion can be ascertained without consideration of pressure or other stress.

The recognition of the permanent state of motion constituting a vortex ring as a determining agent as regards the future course of the system was in fact justly considered by Helmholtz as one of his greatest achievements. The principle had entirely eluded the attention of Lagrange and Cauchy and Stokes, who were the pioneers in this fundamental branch of dynamics, and had virtually prepared all the necessary analytical material for Helmholtz's use. The main import of this advance lay, not in the assistance which is afforded to the development of the complete solution of special problems in fluid motion, but in the fact that it constituted the discovery of the types of permanent motion of the system, which could combine and interact with each other without losing their individuality,* though each of them pervaded the whole field. This rendered possible an entirely new mode of treatment; and mathematicians who were accustomed, as in astronomy, to aim directly at the determina-

* We may compare G. W. Hill's more recent introduction of the idea of permanent orbits into physical astronomy.

tion of all the details of the special case of motion, were occasionally slow to apprehend the advantages of a procedure which stopped at formulating a description of the nature of the interaction between various typical groups of motions into which the whole disturbance could be resolved.

The new train of ideas introduced into physics by Faraday was thus consolidated and emphasized by Helmholtz's investigations of 1858 in the special domain of hydrodynamics. In illustration let us consider the fluid medium to be pervaded by permanent vortices circulating round solid rings as cores; the older method of analysis would form equations of motion for each element of the fluid, involving the fluid pressure, and by their integration would determine the distribution of pressure on each solid ring, and thence the way it moves. This method is hardly feasible even in the simplest cases. The natural plan is to make use of existing simplifications by regarding each vortex as a permanent reality, and directly attacking the problem of its interactions with the other vortices. The energy of the fluid arising from the vortex motion can be expressed in terms of the positions and strengths of the vortices alone; and then the principle of Action, in the generalized form which includes steady motional configurations as well as constant material configurations, affords a method of deducing the motions of the cores and the interactions between them. If the cores are thin they in fact interact mechanically, as Lord Kelvin and Kirchhoff proved, in the same manner as linear electric currents would do; though the impulse thence derived towards a direct hydro-kinetic explanation of electro-magnetics was damped by the fact that repulsion and attraction have to be interchanged in the analogy. The conception of vortices, once it has been arrived at, forms the natural physical basis of investigation, although the older method of determining a distribution of pressure-stress throughout the fluid and examining how it affects the cores is still possible; that stress, however, is not simply transmitted, as it has to maintain the changes of velocity of the various portions of the fluid. But if the vortices have no solid cores we are at a loss to know where even this pressure can be considered as applied to them; if we follow up the stress, we lose the vortex; yet a fluid vortex can nevertheless illustrate an atom of matter, and we can consider such atoms as exerting mutual forces, only these forces cannot be considered as transmitted through the agency of fluid pressure. The reason is that the vortex cannot now be identified with a mere core bounded by a definite surface, but is essentially a configuration of motion extending throughout the medium.

Thus we are again in face of the fundamental question whether all attempts to represent the mechanical interactions of electro-dynamic systems, as transmitted from point to point by means of simple stress, are not doomed to failure; whether they do not, in fact, introduce unnecessary and insurmountable difficulty into the theory. The idea of identifying an atom with a state of strain or motion, pervading the region of the æther around its nucleus, appears to demand wider views as to what constitutes dynamical transmission. The idea that any small portion of the primordial medium can be isolated, by merely introducing tractions acting over its surface and transmitted from the surrounding parts, is no longer appropriate or consistent; a part of the dynamical disturbance in that element of the medium is on this hypothesis already classified as belonging to, and carried along with, atoms that are outside it but in its neighborhood—and this part must not be counted twice over. The law of Poynting relating to the paths of the

transmission of energy is known to hold in its simple form only when the electric charges or currents are in a steady state; when they are changing their positions or configurations their own fields of intrinsic energy are carried along with them.

It is not surprising, considering the previous British familiarity with this order of ideas, that the significance for general physics of Helmholtz's doctrine of vortices was eagerly developed in this country, in the form in which it became embodied through Lord Kelvin's famous illustration of the constitution of the matter, as consisting of atoms with separate existence and mutual interactions. This vortex atom theory has been a main source of physical suggestion because it presents, on a simple basis, a dynamical picture of an ideal material system, atomically constituted, which could go on automatically without extraneous support. The value of such a picture may be held to lie, not in any supposition that this is the mechanism of the actual world laid bare, but in the vivid illustration it affords of the fundamental postulate of physical science, that mechanical phenomena are not parts of a scheme too involved for us to explore, but rather present themselves in definite and consistent correlations, which we are able to disentangle and apprehend with continuously increasing precision.

It would be an interesting question to trace the origin of our preference for a theory of transmission of physical action over one of direct action at a distance. It may be held that it rests on the same order of ideas as supplies our conception of force; that the notion of effort which we associate with change of the motion of a body involves the idea of a mechanical connection through which that effort is applied. The mere idea of a transmitting medium would then be no more an ultimate foundation for physical explanation than that of force itself. Our choice between direct distance action and mediate transmission would thus be dictated by the relative simplicity and coherence of the accounts they give of the phenomena: this is, in fact, the basis on which Maxwell's theory had to be judged until Hertz detected the actual working of the medium. Instantaneous transmission is to all intents action at a distance, except in so far as the law of action may be more easily formulated in terms of the medium than in a direct geometrical statement.

In connection with these questions it may be permitted to refer to the eloquent and weighty address recently delivered by M. Poincaré to the International Congress of Physics. M. Poincaré accepts the principle of Least Action as a reliable basis for the formulation of physical theory, but he imposes the condition that the results must satisfy the Newtonian law of equality of action and reaction between each pair of bodies concerned, considered by themselves; this, however, he would allow to be satisfied indirectly, if the effects could be traced across the intervening æther by stress, so that the tractions on the two sides of each ideal interface are equal and opposite.* As above argued, this view appears to exclude *ab initio* all atomic theories of the general type of vortex atoms, in which the energy of the atom is distributed throughout the medium instead of being concentrated in a nucleus; and this remark seems to go to the root of the question. On the other hand, the position here asserted is that recent dynamical developments have permitted the extension of the principle of Action to systems involving permanent motions, whether obvious or latent, as part of their constitution; that on this wider basis the

* *Cf.* also Hertz on the electro-magnetic equations, § 12, *Wied. Ann.*, 1890. The problem of merely replacing a system of forces by a statical stress is widely indeterminate, and therefore by itself unreal; the actual question is whether any such representation can be coordinated with existing dynamics.

atom may itself involve a state of steady disturbance extending through the medium, instead of being only a local structure acting by push and pull. The possibilities of dynamical explanation are thus enlarged. The most definite type of model yet imagined of the physical interaction of atoms through the æther is, perhaps, that which takes the æther to be a rotationally elastic medium after the manner of MacCullagh and Rankine, and makes the ultimate atom include the nucleus of a permanent rotational strain-configuration, which as a whole may be called an electron. The question how far this is a legitimate and effective model stands by itself, apart from the dynamics which it illustrates; like all representations it can only cover a limited ground. For instance, it cannot claim to include the internal structure of the nucleus of an atom or even of an electron; for purposes of physical theory that problem can be put aside, it may even be treated as inscrutable. All that is needed is a postulate of free mobility of this nucleus through the æther. This is definitely hypothetical, but it is not an unreasonable postulate because a rotational æther has the properties of a perfect fluid medium except where differentially rotational motions are concerned, and so would not react on the motion of any structure moving through it except after the manner of an apparent change of inertia. It thus seems possible to hold that such a model forms an allowable representation of the dynamical activity of the æther, as distinguished from the complete constitution of the material nuclei between which that medium establishes connection.

At any rate, models of this nature have certainly been most helpful in Maxwell's hands toward the effective intuitive grasp of a scheme of relations as a whole, which might have proved too complex for abstract unravelment in detail. When a physical model of concealed dynamical processes has served this kind of purpose, when its content has been explored and estimated, and has become familiar through the introduction of new terms and ideas, then the ladder by which we have ascended may be kicked away, and the scheme of relations which the model embodied can stand forth in severely abstract form. Indeed many of the most fruitful branches of abstract mathematical analysis itself have owed their start in this way to concrete physical conceptions. This gradual transition into abstract statement of physical relations in fact amounts to retaining the essentials of our working models while eliminating the accidental elements involved in them; elements of the latter kind must always be present because otherwise the model would be identical with the thing which it represents, whereas we cannot expect to mentally grasp all aspects of the content of even the simplest phenomena. Yet the abstract standpoint is always attained through the concrete; and for purposes of instruction such models, properly guarded, do not perhaps ever lose their value; they are just as legitimate aids as geometrical diagrams, and they have the same kind of limitations. In Maxwell's words, 'for the sake of persons of these different types scientific truth should be presented in different forms, and should be regarded as equally scientific whether it appear in the robust form and the vivid coloring of a physical illustration, or in the tenuity and paleness of a symbolical expression.' The other side of the picture, the necessary incompleteness of even our legitimate images and modes of representation, comes out in the despairing opinion of Young ('Chromatics,' 1817), at a time when his faith in the undulatory theory of light had been eclipsed by Malus's discovery of the phenomena of polarization by reflection, that this difficulty 'will probably long remain, to mortify the van-

ity of an ambitious philosophy, completely unresolved by any theory': not many years afterwards the mystery was solved by Fresnel.

This process of removing the intellectual scaffolding by which our knowledge is reached, and preserving only the final formulæ which express the correlations of the directly observable things, may moreover readily be pushed too far. It asserts the conception that the universe is like an enclosed clock that it wound up to go, and that accordingly we can observe that it is going, and can see some of its more superficial movements, but not much of them; that thus, by patient observation and use of analogy, we can compile, in merely tabular form, information as to the manner in which it works and is likely to go on working, at any rate for some time to come; but that any attempt to probe the underlying connection is illusory or illegitimate. As a theoretical precept this is admirable. It minimizes the danger of our ignoring or forgetting the limitations of human faculty, which can only utilize the imperfect representations that the external world impresses on our senses. On the other hand such a reminder has rarely been required by the master minds of modern science, from Descartes and Newton onwards, whatever their theories may have been. Its danger as a dogma lies in its application. Who is to decide without risk of error, what is essential fact and what is intellectual scaffolding? To which class does the atomic theory of matter belong? That is, indeed, one of the intangible things which it is suggested may be thrown overboard, in sorting out and classifying our scientific possessions. Is the mental idea or image, which suggests, and alone can suggest, the experiment that adds to our concrete knowledge, less real than the bare phenomenal uniformity which it has revealed? Is it not, perhaps, more real in that the uniformities might not have been there in the absence of the mind to perceive them?

No time is now left for review of the methods of molecular dynamics. Here our knowledge is entirely confined to steady states of the molecular system: it is purely statical. In ordinary statics and the dynamics of undisturbed steady motions, the form of the energy function is the sufficient basis of the whole subject. This method is extended to thermo-dynamics by making use of the mechanically available energy of Rankine and Kelvin, which is a function of the bodily configuration and chemical constitution and temperature of the system, whose value cannot under any circumstances spontaneously increase, while it will diminish in any operation which is not reversible. In the statics of systems in equilibrium or in steady motion, this method of energy is a particular case of the method of Action; but in its extension to thermal statics it is made to include chemical as well as configurational changes, and a new point appears to arise. Whether we do or do not take it to be possible to trace the application of the principle of Action throughout the process of chemical combination of two molecules, we certainly here postulate that the static case of that principle, which applies to steady systems, can be extended across chemical combinations. The question is suggested whether extension would also be valid to transformations which involve vital processes. This seems to be still considered an open question by the best authorities. If it be decided in the negative a distinction is involved between vital and merely chemical processes.

It is now taken as established that vital activity cannot create energy, at any rate in the long run which is all that can from the nature of the case to be tested. It seems not unreasonable to follow the anal-

ogy of chemical actions, and assert that it cannot in the long run increase the mechanical availability of energy—that is, considering the organism as an apparatus for transforming energy without being itself in the long run changed. But we cannot establish a Carnot cycle for a portion of an organism, nor can we do so for a limited period of time; there might be creation of availability accompanied by changes in the organism itself, but compensated by destruction and the inverse changes a long time afterwards. This amounts to asserting that where, as in a vital system or even in a simple molecular combination, we are unable to trace or even assert complete dynamical sequence, exact thermodynamic statements should be mainly confined to the activity of the existing organism as a whole; it may transform inorganic material without change of energy and without gain of availability, although any such statements would be inappropriate and unmeaning as regards the details of the processes that take place inside the organism itself.

In any case it would appear that there is small chance of reducing these questions to direct dynamics; we should rather regard Carnot's principle, which includes the law of uniformity of temperature and is the basis of the whole theory, as a property of statistical type confined to stable or permanent aggregations of matter. Thus no dynamical proof from molecular considerations could be regarded as valid unless it explicitly restricted the argument to permanent systems; yet the conditions of permanency are unknown except in the simpler cases. The only mode of discussion that is yet possible is the method of dynamical statistics of molecules introduced by Maxwell. Now statistics is a method of arrangement rather than of demonstration. Every statistical argument requires to be verified by comparison with the facts, because it is of the essence of this method to take things as fortuitously distributed except in so far as we know the contrary; and we simply may not know essential facts to the contrary. For example, if the interaction of the æther or other cause produces no influence to the contrary, the presumption would be that the kinetic energy acquired by a molecule is, on the average, equally distributed among its various independent modes of motion, whether vibrational or translational. Assuming this type of distribution to be once established in a gaseous system, the dynamics of Boltzmann and Maxwell show that it must be permanent. But its assumption in the first instance is a result rather of the absence than of the presence of knowledge of the circumstances, and can be accepted only so far as it agrees with the facts; our knowledge of the facts of specific heat shows that it must be restricted to modes of motion that are homologous. In the words of Maxwell, when he first discovered in 1860, to his great surprise, that in a system of colliding rigid atoms the energy would always be equally divided between translatory and rotatory motion, it is only necessary to assume, in order to evade this unwelcome conclusion, that 'something essential to the complete statement of the physical theory of molecular encounters must have hitherto escaped us.'

Our survey thus tends to the result, that as regards the simple and uniform phenomena which involve activity of finite regions of the universal æther, theoretical physics can lay claim to constructive functions, and can build up a definite scheme; but in the domain of matter the most that it can do is to accept the existence of such permanent molecular systems as present themselves to our notice, and fit together an outline plan of the more general and universal features in their activity. Our

well-founded belief in the rationality of natural processes asserts the possibility of this, while admitting that the intimate details of atomic constitution are beyond our scrutiny and provide plenty of room for processes that transcend finite dynamical correlation.

Joseph Larmor.

INLAND BIOLOGICAL LABORATORIES.

The following informal notes have been received concerning the season's work in various summer laboratories and experiment stations:

Of the research work carried out on the Great Lakes under the auspices of the United States Fish Commission, Professor Reighard says: The work has been purely research work and it was understood from the start that it should be of a fundamental scientific character rather than directed toward the immediate solution of questions of supposed practical importance.

The funds available have not permitted of carrying on the work for more than two months of each summer. During the summers of 1898 and 1899 it was carried on chiefly at Put in Bay, Ohio, (an island in the western end of Lake Erie, at which there is a hatchery of the Commission). By removing the internal fittings of the hatchery it was temporarily converted into a laboratory for each summer's use. This laboratory has been in every way amply equipped. There is gas and water, a small steamer and a supply of other boats. It is intended that work should begin on the first of July, but owing to delay in appropriation bills and to other causes it may happen, as it did this year, that no authorization for the commencement of the work can be issued until the end of June or even the early part of July. Supplies must then be ordered, arrangements made with workers and the hatchery converted into a laboratory. The difficulty involved in undertaking to do this after the first of July for work which is to continue only two months, led this year to the trial of a different plan. Instead of opening the Put in Bay laboratory an effort is being made to carry on the work by means of individual investigators or small parties working independently. It is hoped that work carried on in this way can be continued over a longer period, even during a part of the college year.

The investigations carried on at the laboratory (and elsewhere during the present summer) are as follows:

BOTANICAL WORK.

1. *The Algæ of Lake Erie.*—Dr. Julia W. Snow has been engaged during each of the three seasons and is now engaged in the determination of the algæ of the Lake and in working out their life histories by means of cultures. As many of them assume different forms under different conditions, it is necessary to cultivate them and no final identifications are possible until the life history of each is known. This is of course a labor of years and involves a consideration of the relation of the various algæ groups to the nutritive substances contained in the water, that is, it leads into bio-chemistry. It is expected that results already obtained will be made ready for publication during the coming year.

2. *The larger Aquatic Plants.*—During the first season Mr. A. J. Pieters of the Department of Agriculture at Washington undertook a study of the larger aquatic plants with the purpose of determining whether they are wholly dependent on the water for nutrition or partly on the soil. Mr. Pieters' results are now in press. He did not get much further than a determination of the various soils present on the Lake bottom and the relation of the plants to them. During the second season and during the present season Mr. R. H. Pond, an assistant in Botany at the University, has car-

ried on the work by experimental methods, Mr. Pieters' duties at Washington not permitting him to continue it. Mr. Pond expects to conclude his work by the end of the next academic year.

ZOOLOGICAL WORK.

1. *Collections.*—During the first two seasons extensive collections were made of the invertebrate fauna of the Lake, also collections of the contents of fish stomachs and of the parasites of the aquatic vertebrates. During the past summer a camping party was sent about the shore of the Lake for the purpose of making these collections. Some of the material has been distributed to specialists, but no reports have as yet been received. Pending this, collecting has been discontinued.

2. *Plankton Work.*—This has been carried on by myself with the cooperation of Dr. H. B. Ward of the University of Nebraska. Apparatus has been devised for measuring the actual flow of water through the plankton net. This apparatus is now being rated at the hydraulic laboratory of the University of Ohio, at Columbus. When this work is finished the apparatus will be used in the Lake. It is hoped by this apparatus to settle the question of the actual availability of plankton nets for quantitative work, to find the actual volume of water strained by them and to what extent they become clogged with use.

The Illinois State Laboratory of Natural History has a biological station under the direction of Professor S. A. Forbes, which is not a summer laboratory merely, but is established for continuous investigation of the aquatic life of the State, and is in active operation throughout the year. It is an institution for research and not for instruction, the work being done by a Superintendent and a paid staff.

At present two lines of work are in progress. (1) Systematic study of the ichthyology of the Station field and of other parts of the State reached by excursions, together with the painting of a series of illustrations of the fishes of the State made in the field from the living specimens. (2) An analysis and statement of the results of five years of plankton work done on the Illinois river, at Havana and Meredosia. The work on ichthyology will result in the publication of a State report covering the whole subject for the State of Illinois, a large part of the manuscript for which has already been prepared; and that on the plankton will be ready for publication January 1st, in the form of an independent Bulletin article.

In the absence of Professor C. H. Eigenmann, the Indiana University Biological Station was this summer under the direction of Dr. Robert E. Lyons. The research work being done was as follows: Ed. Showers, 'The Vertical and Horizontal (qualitative and quantitative) Distribution of Bacteria in the Lake'; Mr. Hunt, 'The distribution of Bacteria in the Air'; Mr. Rush, 'The Rôle of the Horseflies and Mosquitoes in carrying Infectious Diseases'; Dr. Baldwin, 'On an Intro-utero cure for Hog Cholera'; Dr. Howe, 'On the Plankton of the Lake.' Mr. Clark and Mr. Ek are completing their floral survey of the Lake; Mr. Ramsey is continuing the faunal survey; Mr. Moenkhaus is conducting the survey work of the Lake.

The entomologic field station of the New York State Museum is a station for the study of the biology of aquatic insects. Professor James G. Needham, of Lake Forest University, is in charge. Investigation is its sole object at present: no courses of study are offered. The work is mainly done by Professor Needham and Mr. Cornelius Betten, assistant in biology in Lake Forest University, with the occasional assistance of visiting specialists, to whom the

facilities of the Station are offered. The location is admirably suited to the purposes in view. Near at hand there is a very great variety of aquatic situations and a rich and varied aquatic fauna. The aquatic insects most abundantly represented are caddice flies, dragon flies, may flies and aquatic Diptera: much work has already been done here on the life histories, habits and ecology of these.

The Station for the present season finds quarters in the Adirondack Fish Hatchery building at Saranac Inn, where an abundance of running water renders possible the rearing of the insects which live in the limpid streams outside. The initial equipment of the station was excellent, and the work has been prosecuted under favorable circumstances. While no instruction is offered here, an effort will be made to report the result of the work in such form as to be available for the use of teachers of natural science generally.

The houseboat 'Megalops' of the Zoological Survey of Minnesota has just been closed and put into winter quarters near the southern boundary of the State. This houseboat was built at Mankato a year ago last spring, for the purpose of investigating the fauna of the Mississippi and Minnesota rivers from Mankato to the southern boundary of the State. Special attention was given to the fishes. The reptiles, amphibia and mollusks also received considerable attention. The smaller forms are to be studied more carefully at stations to be established where the experience of the past two seasons has found the conditions to be most favorable. It is the intention of the Director of the Survey, Professor Nachtrieb, to use the houseboat as headquarters for these investigations near the head of Lake Pepin. Thus far the houseboat has proved to be a most satisfactory and economical institution for such work. The results of the investigations will be published in the Zoological Series of the Reports of the Geological and Natural History Survey of Minnesota.

Some very excellent and satisfactory work has also been done on the birds of Minnesota during the past season. This work is under the immediate direction of Dr. Thomas S. Roberts. The work on the fishes is under the immediate direction of Professor U. O. Cox, of Mankato.

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*THE COLORADO POTATO BEETLE.**

The Colorado potato beetle *Leptinotarca decem-lineata* Say, is one of several closely allied forms that have spread over North America until one or more is found in almost every part of the continent east of the Rocky Mountains, and south of 50 degrees north.

The parent form *L. undecem-lineata*, seems to have originated in the northern part of South America. When the great northward migration came following the retreat of the continental glacier, it is probable that this form also went north, and in its journey encountered the diversified Mexican region, where it split into several racial varieties, each characteristic of a certain climatic area. As the advancing hordes spread northward, three well marked climatic belts were encountered, the Pacific Coast belt of Mexico, and the Mexican table land, and the low Gulf Coast area.

From the Pacific coast strip not much evidence is obtainable as to the presence of these beetles, or the changes produced upon them. On the table-land, however, the form was diminished in size and the pigmented areas are broken up into smaller spots. This form which is called *L. multilineata* grades into *L. undecem-lineata* on the south, and to the northern part of the Mexican plateau passes imperceptibly into *L.*

* Abstract of a paper presented before the Section of Zoology of the American Association.

decem-lineata, the latter form extending northward along the eastern slope of the western highlands, and west of the arid region, spread as far north as the Canadian boundary, and perhaps even farther.

The low humid Gulf coast area also produced a characteristic form, *L. juncta*, which can be traced into the parent form in the lower part of the Mexican region, and which spread up the Mississippi valley into southern Illinois, and along the Gulf, and up the Atlantic coast to Maryland.

Such was the distribution of these beetles until the middle of the nineteenth century. About 1840 the potato began to be cultivated in the cañons of Colorado, and *L. decem-lineata* soon left its old food plant, *Solanum rostratum*, for the new *S. tuberosum*, causing, no doubt a rapid increase in the number of the species. In 1849–50 began the rush to California from Council Bluffs west along the Platte river. There are several accounts extant of the sale of potatoes to emigrants by thrifty Irishmen at Omaha and Council Bluffs, and judging from the haste and carelessness of the emigrants there can be no doubt that potatoes were lost or thrown away along the route. The valley being fairly fertile and moist, these potatoes grew until there was a more or less continuous line of potato plants from Council Bluffs along the Platte river to the cañons of the Colorado region. Along this route *L. decem-lineata* moved eastward so that in 1859, ten years after the '49 rush to California, the beetle is reported as injurious to crops at a point just east of the arid belt and about on the 98th meridian. During the next twenty years it reached the Atlantic coast and covered the entire country between latitudes 37° and 47° north.

Connected with the advance of this form there are several features of general interest. The beetle is double-brooded over the whole area, but it is only the second, or August brood, that flies to any great extent, and, consequently, has pushed into the hitherto unoccupied territory. However, the new areas covered have not been overrun by the unaided flying of the beetles eastward. If no outside agent were at work the beetles would fly west as often as east, so that alone no great advance would be made. It is to be noted that the beetle is not a strong flyer, that it is unable to advance successfully against the wind, and that the direction of its flight is, therefore, controlled largely by the wind. In August and September there are established certain well defined wind tracts, and it is along these that the beetle has advanced with the greatest rapidity, the advance being directly proportional to the wind velocity in any region for a given year. The most rapid advance has been in the track of the prevailing westerlies along the lakes and down the St. Lawrence valley. This point is proved by contrasting the northern advance with the extremely slow advance southward, the latter being due in part to the temperature and moisture conditions, but largely to the variable winds of the southern part of the United States in late summer.

The entire advance of this form east of the arid belt has been independent of lines of travel, there being no evidence of any considerable transportation by human agencies.

At the present time the beetle is found throughout all that portion of North America which lies east of the Rocky Mountains and between latitudes 32° and 55° north. It has been found as far north as 65°, but to my knowledge has not gained a foothold in Labrador or Newfoundland.

It is interesting to note that as *L. decem-lineata* has advanced *L. juncta* has retreated before it. Formerly *juncta* was abundant in southern Illinois, and in Delaware, Maryland and New Jersey, but now it has retreated to the Carolinas on the Atlantic coast and to lower Mississippi on the south.

In a relatively short time this insect has overspread a large area and has encountered various climatic conditions and the question at once arises as to whether these conditions have yet produced any appreciable effects. If, using the Colorado specimens as a type, we compare these quantitatively with specimens from other parts of the United States, the presence of several already well-marked varieties is shown. These are correlated closely with the climatic conditions of the several areas for the months of June, July and August. Without going into details at the present time, I shall simply mention the areas in which these incipient varieties are forming. In the northwest is found the well-marked 'Dakota type' which has spread over the Dakotas, Manitoba and parts of Wisconsin and Nebraska. In the southwest is the 'Texas type,' found in northwest Texas, Arkansas, Kansas and New Mexico. In the region about the Great Lakes there is the 'Lake type,' and in the northeast is found the 'New England type,' which covers New England and Nova Scotia, while in the southeast there are the 'Atlantic coast type,' and the 'Southern Appalachian type.'

These types are not as yet far removed from one another, nor are they easily seen on inspection. However, measurements show changes in dimensions and in coloration in the several areas, so that there can be no doubt that there are slowly forming several races of the beetle in different parts of the United States and Canada as a direct result of the diversity of environment. As 45,000 specimens from different parts of the United States have been studied the error from too few individuals is obliterated.

W. L. Tower.

THE EIGHTH INTERNATIONAL GEOLOGICAL CONGRESS AT PARIS.

The Eighth Congress of Geologists assembled in the *Palais des Congrès*, Thursday, August 16th, at 4 p. m. M. Karpinsky, retiring president, gave the opening address and was followed by the president, M. Albert Gaudry, in a cordial address of welcome. The geologists of the continent were well represented and appeared in full dress with all their medals and decorations. England and America were comparatively inconspicuous both in numbers and in attire.

The registration was 288 upon the second day. All the most distinguished geologists of Europe were in attendance. England sent an exceptionally small number. Among the Americans present were Messrs. Stevenson, Hague, Osborn, Ward, Willis, White, Cross, Scott, Todd, Kunz, Choquette, Adams, Matthew, Ries, Willmott, Rice; the three first named were chosen as vice-presidents. M. Barrois closed the first session with reports upon the program and upon the geological excursions which were arranged in a most admirable manner before, during and after the congress. On the same evening a delightful reception was given by the Geological Society of France in their new quarters, Rue Danton 8. On Friday morning the section of geology and tectonics, presided over by M. Geikie, held its first session, with communications by Geikie, Chamberlin, Joly, Lapparent, Munier-Chalmas and Roland. In the afternoon the section of mineralogy and petrography listened to a report of the petrographical commission by M. Lacroix. In this connection may be mentioned the fact that during the Congress plans for an international petrographical journal were successfully matured.

On Saturday at ten o'clock the Section of Applied Geology met under the direction of M. Schmeisser, and at one o'clock M. Zittel presided over the first session of the Stratigraphy and Paleontology. The important business of this session was the discussion of the final report of the strati-

graphical commission which was presented by M. Zittel in the absence of its chief advocate, M. Renevier; difference of opinion chiefly concerned the proposed substitution of the terms Paleozoic, Mesozoic and Cenozoic for Primary, Secondary and Tertiary; when this proposal was practically withdrawn by M. Bertrand the report was adopted. The Congress adjourned to a reception by M. and Mme. Gaudry in the new gallery of Paleontology in the Jardin des Plantes. The installation of fossils and vertebrates in this gallery and the comparative anatomical museum on the lower floor rearranged by M. Filhoz were greatly admired. Sunday, Monday, Wednesday, Friday and Sunday following were devoted to very attractive excursions to the classic horizons in the neighborhood of Paris and to the scientific features of the Exposition, while four more days were assigned to the work of the Sections, including the closing session of Monday, August 27th.

The papers were successively brought together in groups as follows: general geology, petroleum-bearing rocks and paleozoic succession, geology of Syria, Africa and Madagascar, petrography and vulcanism, glacial phenomena and report of international commission on glaciers, report on nomenclature and the geological chart of Europe, geology of North and South America (communications by Osborn, Scott, Matthew and Walcott). Among matters of detail the following deserve mention: the award of the 'Leonide Spendiaroff international prize' to M. Karpinsky, who insisted upon transferring the money award to some young French geologist; the announcement by M. Keilhac of a new geological review, the *Geologisches Centralblatt;* the selection of Vienna as the meeting place for the ninth congress.

The unbounded hospitality of the government, of the Exposition authorities and of the members resident in Paris was greatly appreciated and enjoyed. The President of the Republic invited all the *Congressistes* to a charming afternoon reception and open air theatricals in the garden of the Elysée palace. There was also a liberal distribution of seats and boxes in the national theatres. M. and Mme. Gaudry and Prince Roland Bonaparte gave two evening receptions. On Saturday, August 25th, an elaborate banquet was given by the French Geologists in the new *Hôtel du Palais d'Orsay.* The excursionists also were indebted for liberal reductions in fare made by the French railroads. Socially the Congress was a great success, the receptions as well as the intervals between the sessions affording abundant opportunities for personal intercourse, and it is well recognized that this, rather than the presentation of long and serious papers, is the chief end of a congress. At the same time it was felt by many present that several of the papers presented were not of a high order or general character and should not have been admitted at all, and that the time arranged for discussion was insufficient. The scientific spirit was naturally somewhat disturbed by the proximity of the Exposition and the *Salle des Congrès* itself was not well suited for the meetings in point of acoustics or apparatus. But for these features the French geologists were not responsible and, with one or two minor exceptions, the arrangements over which they had complete control were excellent. This is especially true of the excursions which were admirably prearranged and conducted; the *Guide Géologique de France,* prepared for the twenty great and many lesser excursions, is really a voluminous treatise and resumé of the most recent geological researches in France, attractively illustrated by 372 figures and 25 plates; it sets a new standard for future congresses.

All who attended the Congress felt more than repaid for the journey to Paris and deeply indebted to the genial President, Professor Albert Gaudry, to the indefatigable and much beloved Secretary, Professor Charles Barrois, and to his associates, Messrs. Thévenin, Von Arthaber and Zimmermann.

H. F. O.

SCIENTIFIC BOOKS.

Introduction to Zoology. By Charles Benedict Davenport and Gertrude Crotty Davenport. New York, The Macmillan Co. 1900. Pp. xii + 412; 311 illustrations. Price, $1.10.

The purpose of this new text-book, as indicated by its secondary title, is that of 'a guide to the study of animals for the use of secondary schools.' Unlike most of its predecessors among zoological books for secondary schools its title is not misleading, for the book is sent forth not as an 'elementary zoology' but as an *introduction* to the study of animals. It does not pretend to be a treatise on 'zoology' from the varied aspects of comparative anatomy, embryology, and physiology, but rather it attempts a presentation of facts which may well pave the way for advanced study of the special sub-sciences of zoology. But in addition to writing an introduction for students who may go deeper into zoological studies, the authors have recognized the important fact that 'the vast majority of secondary students, are not to be zoologists, but rather men of affairs.' Although this view has been gaining recognition in recent years, this is the first text-book which seems to have been planned with consideration for the needs of the 'vast majority' who are limited to a short elementary course in zoology.

Contrasted with the elementary books on zoology which have appeared during the last decade, the plan of this book is decidedly new; for it places no emphasis upon comparative anatomy, which has strongly characterized recent zoological teaching in most secondary schools. There is no description of internal structure of animals, and consequently no discussion of fundamental physiological processes. The book deals with common animals, and their habits, homes, their life histories, and their systematic, economical and ecological relations. In short, the book is a *modern* Natural History full of the spirit and the charm which characterized the old-time books on that subject.

As a text-book the 'Introduction to Zoology' is intended to accompany the well-known outline of laboratory study in zoology which Professor Davenport prepared several years ago, and which was published as an 'Outline of Requirements in Zoology,' Lawrence Scientific School, Harvard University. A revised reprint of this outline forms an appendix to the book. The order of treatment in the text follows that of the outline for laboratory work, beginning with insects and following with other arthropods, worms, mollusks, echinoderms, cœlenterates, protozoa, and the vertebrates.

Considerable attention is given to classification. Twenty chapters have appendices with keys for identification of common families and orders. Both common and scientific names of animals are freely used in the text, and footnotes give the meaning and derivation of the technical names.

The book is liberally illustrated both by figures from well-known works and by numerous new photographs of the natural objects. With regard to the photographs it must be regretted that many are imperfect and do not well illustrate. One feels convinced that good outline drawings would in many cases have been more instructive, particularly in the case of small animals like insects. However, many of the photographs are excellent and add a charm to the book.

On the whole the book is written in an entertaining style, and can scarcely fail to arouse interest concerning our common animals. The authors have well presented the natural history aspect of zoology. Teachers who read the book will probably agree that for liberal secondary education no other phase of zoology would be more important, but many readers will doubt the wisdom of omitting from secondary education all reference to the essential facts concerning the internal structure and the fundamental physiological processes of animals.

The book will surely find a place in secondary

schools whose teachers recognize that most of their pupils are studying zoology for use in everyday life and not as preparation for advanced study in college. Moreover, college officers in charge of admission requirements will probably give more favor to such a course in elementary zoology than they have accorded the purely morphological study which is now so much in vogue in secondary schools.

MAURICE A. BIGELOW.
TEACHERS COLLEGE, COLUMBIA UNIVERSITY.

Oysters and Disease. An account of Certain Observations upon the Normal and Pathological Histology and Bacteriology of the Oyster and other Shell-fish. By W. A. HERDMAN, D.Sc., F.R.S., and RUBERT BOYCE, M.B., London. George Philip and Son. 1899. Lancashire Sea-fisheries Memoir No. 1.

In this thin volume Professors Herdman and Boyce, record the results of an investigation extending over a period of three years and, although they have not actually established a connection between oysters and disease, they have produced the most important contribution which has yet appeared upon the subject, which is one of considerable scientific and unusual popular interest.

The disputed question as to the cause of green oysters has been re-examined, with the result that several forms of greenness have been recognized and studied. But little is added to our knowledge of the well-known oysters of Marennes, the authors being in practical accord with most previous investigators, but concerning the green oysters of Falmouth and certain green American oysters laid down in the vicinity of Liverpool they reach results divergent from the views held by previous workers and more in accord with popular beliefs.

Copper in minute quantities is normally present in all oysters, but in the green Falmouths and Liverpool Americans it is found in unusual amounts. In the greenest of the American oysters as compared with the whitest, the proportion is 3.75 : 1, calculated per oyster, and 3.63 : 1, calculated on the ash, and a careful study of the distribution of the copper by chemical and histo-chemical methods demonstrates that it is the cause of the greenness.

Some years ago Dr. Ryder, as noted by the authors, studied a case of leucocytosis in American oysters, although he did not determine the presence of copper nor appreciate the true cause of the greenness. The reviewer has examined during recent years, a great many green oysters, but in no case has the greenness been in the leucocytes of the blood of the heart and the sinuses and tissues of the mantle, as described by Ryder and the present authors, nor in those which were tested, has the copper been present in abnormal quantities or unusual distribution. The specimens rather resembled the poor but harmless Dutch oysters described by Herdman and Boyce, and it would appear that we have in America, as in Europe, several kinds of green oysters, that in which the color is due to copper being comparatively rare.

The connection of oysters with the transmission of infectious diseases, especially typhoid and enteric fevers, is carefully considered. Bacilli of the colon group are frequently found in oysters sold in towns, but there is no evidence that they occur in those living in pure sea-water. The experiments show that pure sea-water is inimical to the growth of typhoid bacilli and that they do not multiply either in the alimentary tract nor in the tissues of the living oyster. *B. typhosus* was not found in any of the oysters obtained from dealers or directly from the sea, but from inoculated specimens the bacilli were obtained up to the tenth day, although the results indicate that they perish during passage through the intestines.

Oysters and other mollusca obtained from dealers frequently contain a bacillus possessing the characters of Klein's *B. enteritidis sporogenes*, presumptively resulting from sewage contamination, but it was found that the infected oysters could be cleansed by washing in clean running sea-water. It is evident, therefore, that by changing oysters from an infected bed to one where the surroundings are pure they may be purged of their dangerous qualities. The authors urge, in conclusion, that, by legislative action and cooperation among growers, steps be taken to prevent sewage contamination of the oyster beds from which the markets are supplied.

Several facts are added to our knowledge of the minor anatomy of the oyster, especially interesting being the demonstrated change in the primitive retractor pedis muscle whereby it becomes a dilator oris.

The paper is well illustrated.

H. F. Moore.

Washington, August 25, 1900.

Anatomie et physiologie végétale. For the use of students of natural science in universities and agricultural schools, etc. By Professor Er. Belzung. Ancienne Librairie, Germer Baillière et Cie. Paris, 1900. 1699 Figs. 8vo. Pp. iii + 1320.

Professor Belzung is the author of text-books on geology, zoology, animal physiology, and animal paleontology, in addition to two or three botanical works besides the subject of this review. Such breadth of authorship undoubtedly relieves him from any taint of narrow specialism. This experience secures for the book in question, however, no new points of view, since it is a purely formal presentation of the better known facts in botany compiled after the manner of an encyclopedia. Perhaps the freshest portion of the book is that taken up with the subject of fermentation, which is given a treatment not usually accorded this phase of botany in general texts. The final section of the work consists of the 'Conclusions' and is devoted to the general characters of protoplasm and plants usually given in the introductory chapters of such texts.

The book leads chiefly to the examination room, and only the most determined enthusiasm could carry through its use a genuine interest in the study of plants.

D. T. MacDougal.

Report of Competitive Tests of Street Car Brakes. By the Board of Railroad Commissioners of the State of New York. 1899. Albany, Brandon Printing Co., Department Printer, 1900. 8vo. Pp. 60; 67 sheets of diagrams.

The report of the electrical expert, Mr. C. R. Barnes, April 4, 1900, details the origin and progress of the work of the N. Y. State Board of R. R. Commissioners, conducted to ascertain the practicability of insuring greater safety in the operation of street cars moved by cable and by the electric current, comparing the newer forms of brake with the older. It is stated that 295 people have been killed and 1599 injured by the electric railways of the State of New York in three years, as shown by the records of the Board. These figures indicate a rapid increase in this form of mortality, due to rising weights of cars and increasing speeds. Cars are now in use weighing 23 tons and speeds exceeding 50 miles an hour have been attained on suburban lines.

In preparing for these trials Messrs. Barnes and Pierson, the electrical engineer of the Metropolitan R'y Co., designed and constructed an automatic recording apparatus for measuring lengths of run under action of the brake. The apparatus was calibrated on 275 feet of track assigned for the purpose by the railway company and the essential observations and data were derived by use of this instrument; the work being performed in New York on the Lenox Avenue line, in the half-mile between 135th and 146th streets. Sixteen brakes—4 air-brakes, 4 electric, 3 hand-power, 2 friction and 2 'track-and-wheel' brakes—were tried.

The reliability of the air-brake is reported to be thoroughly established and a number of them have come into use. But one electric brake, that of the General Electric Co., is in use to any extent. New forms of the older type, the hand-power brake, were tested. They act directly upon the wheels, as usual. The so-called 'friction-brake' is a friction device on the axle, usually disks rotating with the axle and engaging stationary disks, the two sets arranged to be forced strongly against each other, when in action, by means of ingenious mechanisms. The 'track-and-wheel brake' acts on the tracks as well as the wheel. Photographic reproductions of the autographic diagrams obtained from each brake are published, with appended tables exhibiting results numerically.

The usual experiences in such work with dilatory exhibitors, incomplete outfits and occasional miscarriage of the plans of the Board was observed in these trials; but a large amount of new data in a novel field of re-

search was obtained. The results were classified and an order of standing was determined under the four heads: reliability and simplicity; liability to act when not required; ease of operation; cost of equipment and maintenance.

The most remarkably wide range of prices is reported—$30 to $585, averaging about $200. Eleven of the list tested are authorized for use, and the Board determined that the common form of brake now in use should be replaced by one or another of these, or equally efficient, brakes.

President Vreeland, of the Metropolitan Co., his directors and the executive officers seem to have taken much trouble and to have met most of the expenses of these important pioneer investigations, and his electrical engineer, the master mechanic and the superintendents lent essential aid in the work.

The report can be had by applying to the Board at Albany.

The data may be summarized thus: At 8 miles an hour, a stop was made in from 3 to 8 seconds; at 12 miles in 5 to 9 seconds; at 15 miles, in 6 to 10 seconds; at 16 miles, in 6 to 11 seconds, without sand, and 6½ to 9½ with sand. The distances run ranged from 35 to 66 feet at 8 miles, 58 to 111 at 12 miles, 72 to 203 at 16 miles; averaging for all speeds, from 58 to 133 feet.

A conventional system of checking for 'skidding' wheels was adopted.

All in all, the work must be accepted as an earnest and faithful endeavor to effect, for the first time, a solution of an important problem—one which concerns all railway managements and all travellers on electric street cars very seriously. The report has been criticised as failing to give data relating to dimensions of parts, uncertainty regarding the comparability of brakes differently handled by their exhibitors, and regarding the automatic records. An examination of the apparatus employed, however, shows that the distances traversed were measured by a mechanism positively driven and which, therefore, gave reliable comparison of distances traversed, which measures are the sole basis of all comparisons and are evidently substantially correct. The technical journals generally approve the report as giving valuable and helpful information. Undoubtedly, later investigations will afford opportunities for improvements which this, as all pioneer efforts, indicates to be desirable notwithstanding its evident and admitted defects in time-measurement, the report must be accepted as important. Variations of the time-scale do not affect its conclusions. It is to be hoped that the work will be continued and perfected.

R. H. THURSTON.

Lehrbuch der Photochromie von Wilhelm Zenker; neu herausgegeben. Von PROFESSOR DR. B. SCHWALBE. Braunschweig, Friedrich Vieweg & Sohn.

This is a republication of a work which appeared in 1868, to which has been added a biographical sketch, and a résumé of recent work along similar lines.

It will doubtless surprise the general reader to find that partially successful experiments in photochromy, or the *direct* reproduction of color by photography, were made over a quarter of a century before the announcement of Daguerre's discovery in 1839. As early as 1810 Seebeck obtained colored impressions of the solar spectrum on paper coated with chloride of silver, but the matter attracted but little attention and was soon forgotten.

In 1841 the property which this substance possessed of assuming a color somewhat similar to the hue of the light falling upon it was rediscovered by Herschel, but the possible great importance of the subject does not appear to have been realized until Becquerel, stimulated by Daguerre's discovery, took up the work, and by a laborious series of investigations determined the conditions most suitable for a faithful reproduction of the colors of the original.

Up to the time of the appearance of Zenker's work the almost universal opinion seems to have been that colored compounds of silver (oxidation and reduction products) were formed by the action of the light. Zenker, however, offered a most ingenious physical explanation, as opposed to the chemical theory. He explained the colors as due to the interference of light reflected from thin laminæ of metallic silver, laid down in sheets half a wave length apart, by the action of stationary light waves,

resulting from the interference of the direct wave train with the train reflected from the back surface of the film. In other words, the colors of the photochromes were similar to the colors of the soap-bubble. This is precisely the principle since made use of by Lippman in his beautiful process.

Zenker's book opens with a short elementary account of the nature of light, of no especial interest. Following this comes a very complete account of the work of Seebeck, Becquerel, Poitevin and others. His account of the claims of Hill, the American photographer, are interesting, final judgment of the case being left to the reader.

Full details are given in most cases of the method of preparing the plates, and the reader will find himself strongly tempted to repeat some of these early experiments.

The third portion of the book treats of the theory of photochromy. The colors of the photochromes had been explained in various ways. Some held that colored oxidation and reduction products were formed while others assumed that the chemical action of the light occurring at the surface, formed a film of varying thickness which showed color precisely like the film of a soap bubble. Zenker effectually demolishes this theory by showing that prolonged exposure, by increasing the thickness of the film, should change the color, which is not the case.

He then advances his own beautiful theory, not abandoning the soap film idea, but presenting it in a wholly new light. He conceives the light waves as penetrating the film and suffering reflection at the back surface. The reflected waves interfere with the oncoming waves forming a stationary system, the ether within the film vibrating in nodes, like the string of a musical instrument when sounding a harmonic. He shows us that there will be planes of vibration within the film parallel to the reflecting surface situated half a wave-length apart. In other words the distance between the planes of maximum vibration will depend on the wave-length or color of the light. If the silver is reduced in these planes and not at the nodes (when there is no vibration) we shall have reflecting laminæ formed, which will act like the upper and lower surface of a soap film and show interference colors. The light most copiously reflected under these conditions will be of a color identical with that of the light which formed the laminæ. He describes a number of experiments confirming his theory, but pushes it too far in attempting to explain the color of ordinary objects and the perception of color by the eye in this way.

His book is on the whole a most excellent résumé of the work done up to the time of its publication.

The appendix, in which the further development of the subject is treated by E. Tonn, deals chiefly with matters of theoretical interest. The work of Wiener and Lippmann is discussed in connection with the theory of the reproduction of mixed colors. As a matter of fact there have been very few or no developments since the time of Zenker, except along the lines indicated by Lippmann, and as no details of this process are given, the appendix is likely to be of interest to the physicist rather than to the photographer.

R. W. Wood.

BOOKS RECEIVED.

Grundlinien der anorganischen Chemie. Wilhelm Ostwald. Leipzig, W. Engelmann. 1900. Pp. xix + 795. 18 Marks.

Der Gesang der Vögel. Valentin Häcker. Jena, Gustav Fischer. 1900. Pp. vii + 102. 3 Marks.

Symons's British Rainfall, 1899. Compiled by H. Sowerby Wallis. London, Edward Stanford. 1900. Pp. 251. 10s.

Foundations of Knowledge. Alexander Thomas Ormond. London and New York, The Macmillan Co. 1900. Pp. xxvii + 528.

SOCIETIES AND ACADEMIES.

NEW YORK ACADEMY OF SCIENCES.

SECTION OF GEOLOGY AND MINERALOGY.

At the meeting on May 21st, Dr. A. A. Julien presided and about twenty persons were present. Two papers on the rocks of Mexico were presented. The first was by Mr. G. I. Finlay, entitled 'A New Occurrence of Nephaline Syenite and associated Dikes in the State of Tamaulipas, Mexico, with a review of the distribution of these rocks in North America.' The second paper was a 'Contribution to the

Geology of Part of Sonora, Mexico,' by Mr. B. F. Hill. Both gentlemen are post-graduate students of Columbia University.

The rocks described by Mr. Finlay were sent by Mr. E. D. Self to Professor J. F. Kemp. The nephaline syenite is a very light-colored rock, containing, besides abundant nephaline and an orthoclase, small patches of dark-colored silicates. Under the microscope these are seen to be ægerine augite intergrown with hornblende, and accompanied by magnetite and apatite. Titanite is abundant, with the faces (1–2–3) well developed, and some zircon occurs. The tinguaite associated with this syenite is a holocrystalline porphyritic dike rock, with large phenocrysts of orthoclase, twinned on the Carlsbad law, tabular in habit, parallel to the clinopinacoid. The ground mass which gives the rock an even, dark green color, consists of a felt of tiny blades of ægerine and orthoclase. The ægerines are at times grouped together in bundles around small patches of biotite.

Mr. Finlay then briefly discussed the distribution of similar rocks in the various portions of the United States, and exhibited a very instructive series of comparative charts of the chemical composition of the rocks examined and those of allied groups, the charts being constructed on the principles of the graphic method devised by Professor Hobbs, as worked out by Mr. Finlay.

The second paper, that of Mr. Hill, also treated of Mexican rocks, and the same geographical maps were employed to illustrate both papers. Little has been written about the coal-bearing rocks and their associated eruptives in the state of Senora, Mexico. The work done by Professor Dumble and his associates has thrown considerable light on some of the problems.

In the district investigated are representatives of nearly all the formations from the Archæan granites to the Quarternary sands and gravels. The most important division, however, is the Triassic. The slates, sandstones, quartzites, etc., with coal seams, make up the lower or Bananca division of the Triassic, while an immense series of associated eruptives, including andesites, dacites, tuffs, andesitic, conglomerates, etc., is considered the upper division. To the series of eruptives the name of Lista Blanca has been given. The Lista Blanca has hitherto been considered post-Cretaceous.

In addition to the pre-Cretaceous eruptives, there are numerous intrusives and flows of diorites, rhyolate, and basalt, and in one instance, trachite. It is probable that these are mostly of Tertiary age. The diorites exert a very noticeable effect on the formation of the ore bodies of the region.

Specimens of all the eruptives were brought to New York and studied by Mr. Hill, in thin section, under the microscope. A series of chemical analyses of the type rocks was made and a very clear relation established between the magmas of the different flows. The remainder of the paper dealt with details on the petrographic characteristics of the rocks.

Both papers were discussed by Professor Stevenson, Professor Kemp, Dr. Julien and Dr. White.

THEODORE G. WHITE,
Secretary of Section.

DISCUSSION AND CORRESPONDENCE.

MR. TESLA AND THE UNIVERSE—HUMAN ENERGY AND HOW TO INCREASE IT—HIS PHILOSOPHIZING QUESTIONED.

MR. NIKOLA TESLA has written a long article in the *Century Magazine* for June with the title 'The problem of increasing human energy, with special reference to harnessing the sun's energy.' The paper is profusely illustrated with impressive cuts of electrical experiments which, at first sight, seem convincing. Most readers of the *Century* looked at the striking cuts and glanced at some of the head lines of the article such as 'Development of New Principle'; 'Production of Immense Electrical Movements'; 'The Earth responds to Man'; Interplanetary Communication now probable,' and accepted the headlines on the testimony of the cuts; or else took it frankly for granted that so long an article must certainly prove a great deal.

The present writer has lately gone over the text of the article, pen in hand, and herewith

presents a small portion of his notes. They seem to him to show that the article in question is composed, essentially, of three different kinds of writing. The first kind describes Mr. Tesla's experiments in electricity and shows what he has already accomplished. This work is, no doubt, important. Its value will be appraised by experts. The present writer has no claim to be considered an electrical expert and does not attempt to give an estimate of the achievements referred to. The second describes what Mr. Tesla expects to accomplish in the future. His prophecies are so sanguine, in many cases, that even a general reader may presume to compare them with the comparatively small things already accomplished and to point out how very unlikely it is that any great part of his expectations will be realized within any reasonable future—within Mr. Tesla's own lifetime, for example.

The third element of this article consists of philosophical arguments about things in general —about human life—what it is—the future of the solar system—the solidarity of the human race—the Christian religion—vegetable food—theoretical dynamics—athletics in colleges—drinking water—ozone—education of women—ice—fertilizers—insanity—warfare—flying machines—iron manufacture—aluminium—liquid air—self acting engines—the inhabitants of Mars—etc., etc., etc.

Now these and other matters are interesting in themselves. We are all anxious to obtain new light upon them. We are all more or less competent to judge the conclusions of other people regarding them. It is not too much to say that this portion of Mr. Tesla's paper is in the main so trivial, so superficial, so obviously weak, as to throw doubt upon the whole essay. Many of the subjects treated are the oldest problems of the human race. They have been discussed by every philosopher since Aristotle. It is fairly astonishing to see Mr. Tesla's reasonings in print at this day. They compare with the logic of giants like Spinoza, Kant, Lord Kelvin, Herbert Spencer, and the rest as a baby's prattle to the 'Summa Theologiæ.'

If this judgment seems too harsh the following paragraphs will fully confirm it. No discourtesy is meant to Mr. Tesla. But his paper has been printed. It now belongs to his readers. He must allow them to compare his philosophizing with that of his great predecessors and with the dicta of common sense.

The paper begins by asking profound questions with regard to human life. Whence comes it? What is it? Whither does it tend? "*Though we may never be able to comprehend human life, we know certainly that it is a movement, of whatever nature it may be,*" is Mr. Tesla's answer. A movement?—*one* movement? Are we sure it is a movement, and nothing else? "*Hence, wherever there is life, there is a mass moved by a force.*" A mass? A force? Why not masses, forces, hundreds of them? These beginnings which seem so definite lead to the conclusion that life is a *rhythm*, but this conclusion is at once dropped for the utterly antagonistic conception that man, mankind, is '*a mass urged on by a force.*' A force will urge a mass onward, not swing it rhythmically. We need not linger over this discrepancy, though there might be something to say, if it were worth while.

Mankind is then conceived as *one* physical mass; and Mr. Tesla's proof that this is a true conception is derived from the fact that every one of us feels sympathy with a friend who is hurt. Here is a mixing of two worlds —the world of matter and the world of feeling —which does not tend to clearness. The man born blind thought the sunset like a pleasing friendship. Swedenborg in his idea of the Grand Man who is the sum and integral of all individual men has put the question in a much truer light; but let us pass on. Man is, according to Mr. Tesla, '*a mass*,' one physical mass. Call this physical mass M. M is a quantity which can be expressed in tons or in ounces. Mankind is '*impelled in one direction*'—*one* direction!! by a force f, "*which is resisted by another force R, acting in a direction exactly opposite.*"

The idea in Mr. Tesla's mind is apparently that the force R is the reaction of the first force f. But every reaction is not only opposite to its action but equal to it, according to Newton. Not so in Mr. Tesla's universe. Reactions are opposite to, but less than actions. There is an effective force left over, which, in

his scheme, imparts a velocity V to mankind, M. "*Human energy will then be given* (measured) *by the product* $\frac{1}{2} MV^2$, *in which* M is the *total mass of man in the ordinary interpretation of the term 'mass,'* and V *is a certain hypothetical velocity which, in the present state of science, we are unable exactly to define and determine.*" How learned all this looks! and how foolish it all is! Mankind has a physical mass, no doubt. The *energy* of mankind is the sum of a million different energies, of very different *qualities* as well as of different amounts—spiritual as well as physical. These different energies, being of different kinds, cannot be expressed by a single term. Mr. Tesla's algebraic formula is mere solemn rubbish. It has absolutely no meaning.

There are three ways of increasing human energy, Mr. Tesla says: I. To increase the mass and energy of mankind more children must be born, fewer individuals must die, and the children must be of '*higher velocity*' than the parents (and *velocity* Mr. Tesla takes as exactly equivalent to *enlightenment*). Here Mr. Tesla pauses to discourage college athletics, and to say that although whisky, tea and tobacco shorten human life, yet he does not think that vigorous measures should be taken to suppress the habits of using them. On the contrary he would leave whisky alone, and improve the quality of drinking water. '*Gambling, business-rush, excitement * * * uncleanliness * * * laxity of morals * * * the society-life, modern education and the pursuits of women*' and other matters tend to diminish the mass of mankind, but want of food is the chief cause.

Cattle are food of '*low velocity*' (enlightenment) Mr. Tesla says, and he does not approve of raising cattle, therefore. '*It is certainly preferable to raise vegetables.*' Here he has forgotten his basic principle, unless, indeed, he is prepared to prove that turnips are food of 'high velocity,' *i. e.*, enlightenment. Here, again, as in the case of rhythmic motion, he no sooner lays down a principle than he abandons or neglects it for something quite different. However his vote is for vegetables, and more are wanted. To fertilize the soil more nitrogen is needed. He has an electric method for obtaining nitrogen from the atmosphere (so has Sir William Crookes) and the world's food supply is safe. All this is very well known. There is nothing new about it except the solemn manner in which it is said.

II. The second point is to reduce the force that retards the human mass. This force is a compound of ignorance, stupidity, imbecility, insanity, religious fanaticism, etc. It is not so simple then as Mr. Tesla's 'force R' with which he began. Warfare is a retarding force but Mr. Tesla thinks it will be with us for some time yet, and indulges in a short excursion on flying-machines. "*The flying-machine is certainly coming and very soon. I see no reason why a ruling power like Great Britain might not govern the air as well as the sea. I do not hesitate to say that the next years will see the establishment of an 'air-power,' and its center may not be far from New York*" (possibly in Mr. Tesla's laboratory?). After a couple of pages devoted to warfare, harbor-defense, flying-machines, foreign invasion, international agreements, eternal justice, prehistoric man and his weapons, Mr. Tesla concludes that future battles will be decided by matching one complicated machine (say British) against another (say Russian).

"*Machines will meet in a contest without bloodshed, the Nations being simply interested, ambitious spectators. When this happy condition is realized peace will be assured.*" "*Bloodshed,*" Mr. Tesla thinks, "*will ever keep up barbarous passions.*" Hence we must '*produce a machine capable of acting as though it were a part of a human being.*' Such a machine may be destroyed but no blood will flow. Mr. Tesla has not yet produced a machine of the sort but he means to do it.

He tells us that as a boy he noticed that whatever he thought of he saw. He visualized words in his mind. By attention he discovered that every occurrence in his mind was suggested by some previous outside occurrence or object. Hence, he was not a free agent, but played upon by his environment. He was the sport of the universe—an automaton. "*I have demonstrated, to my absolute satisfaction, that I am an automaton endowed with power of movement, which merely responds to external stimuli beating on its sense-organs, and thinks and acts and moves accordingly.*" He may be an automaton; but if he thinks that the foregoing argument proves

it, he is no logician. Being an automaton himself Mr. Tesla proceeded to make another automaton. He consented to make it full-grown to save time. It was also unnecessary to endow it with the power of propagating its kind, since Mr. Tesla himself could make more machines when he wanted them. He likewise consented to make it without a mind, because a mind '*I could easily embody in it by conveying to it my own intelligence.*'

With these slight differences from the Garden of Eden Mr. Tesla's workshop has turned out a kind of electrical boat or animated bath-tub (see the cut) whose movements can be controlled from a distance. This machine '*behaved just like a blindfolded person obeying directions received through the ear.*' It had a '*borrowed mind.*' In fact, it had no mind at all, except in Mr. Tesla's confused terminology. It had the same kind of a mind as a Waltham watch. It is now Mr. Tesla's intention to build an '*Automaton*' '*which will have its own mind.*' "*It will be capable of distinguishing between what it ought and what it ought not to do.*"

Of course, such words are merely quibbles. In exactly the same sense a steam-engine has its own mind, and distinguishes what it ought from what it ought not to do. So did Maelzel's mechanical duck. So did Babbage's calculating engine. So does every device. Either the words mean nothing new; or else they are deceptive quibbles. It does not mend matters to say: '*my ideas on this subject have been put forth with deep conviction, but in a humble spirit.*'

Universal peace will be realized, he says, "*when all darkness shall be dissipated by the light of science, when all nations shall be merged into one, and patriotism shall be identical with religion, when there shall be one language, one country, one end, then the dream will have become reality.*" To bring about these desirable conclusions, an automatic fighting machine is necessary. Mr. Tesla is now engaged on the question automatically.

III. But all this while the main point has been lost sight of in divagations. How to increase the forces moving the human mass is the question. For reasons not adduced Mr. Tesla declares that '*the resultant of all these forces is always in the direction of reason.*' Every individual man is an automaton, we have seen, and will act unreasonably if played upon by certain forces. But mankind, which is made up of men, always acts reasonably. 'Tis strange; one seems to recall instances from history that refute the assertion. And indeed, Mr. Tesla himself does not really believe it. What is this busy world, he asks, but 'an immense clock-work?' A 'reasonable' clock-work! He finds, finally that "*the great problem of increasing human energy is answered by the three words: Food, Peace, Work.*" "*These three words,*" he says "*sound the key-note of the Christian Religion.*" One had supposed that Faith, Hope and Charity were the key-notes of the Christian religion; and that this religion had no message at all to a world of automatic men.

With a touching little eulogy on iron, and the prediction that aluminum is soon to take its place, and a good word for coal and for gas-engines, he passes on to the question of obtaining energy direct from the sun, and discusses the "*possibility of a self-acting engine or machine, inanimate, yet capable, like a living being, of deriving energy from the medium.*" His conclusion is that it is possible though it cannot be produced for a long time yet. It is not pressing, then, to discuss his results. We will wait until some are forthcoming.

The next paragraphs of Mr. Tesla's long paper are taken up with the description of his experiments on electrical matters, wireless telegraphy (which Marconi independently discovered and has made practical), etc. Into these we will not follow him, except to say that he claims to be able to produce electrical effects on the planets Venus or Mars by methods which he is very careful not to explain. He expects an answer, too: "*That we can send a message to a planet is certain, that we can get an answer is probable; man is not the only being in the Infinite gifted with a mind.*"

We might go on page by page, pointing out error, extravagance and bathos like the preceding. There seems to be no special need to go further. It should be evident to any impartial reader that the value of Mr. Tesla's general philosophical speculations and opinions is exactly *nil.* The value of his work in elec-

tricity must be judged by experts. The weight of his predictions as to future discoveries would be greater if his judgment on things in general were less unsound. It is passing strange that such loose reasonings can find a publisher. It is to be hoped that they will gain little credence from his readers. A line from Plato's Republic applies here (changing a word) to wit: "I verily believe that it is a more venial offence to be the involuntary cause of death to a man than to deceive him concerning scientific truth."

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BOTANICAL NOTES.

A NEW LABORATORY MANUAL.

DR. CLEMENTS and Principal Cutter, the former of the botanical staff of the University of Nebraska, and the latter of the Beatrice (Nebr.) High School have brought out what must prove to be a very helpful book for those teachers of Elementary Botany who wish to give their pupils a good course in laboratory work. There has been an increasing demand on the part of University professors that the high schools should lay such a solid foundation in the sciences that the subsequent work in the university could safely be built upon it. This has wrought a radical change in the methods of teaching chemistry and physics in the high schools which fit their pupils for university entrance. For many years some of the botanists have been demanding laboratory training in elementary botany for Freshmen entrance, but while the schools have made some progress, it is a curious fact that no serious attempt has hitherto been made to supply the high schools with a scientific manual comparable to the many excellent works of this character in chemistry and physics.

The authors of the 'Laboratory Manual of High School Botany' have attempted to make a book which is at once practicable in the average high school, as well as strictly scientific. The pupil who covers the work here laid out will be prepared to go forward in college and university classes without the necessity of unloading and unlearning a lot of rubbish, while at the same time if he should go no further with his studies he has had the satisfaction of knowing that he is in the possession of a considerable body of useful information in regard to the structure and actions of plants. The general plan of the book may be obtained by a glance at the titles of the chapters, as follows: General Directions, Plant Structure, or Histology, Structure and Classification, Phytogeography, Synopsis of the Larger Groups of the Vegetable Kingdom, Physiology, Appendix (containing suggestions to teachers), and Glossary.

ORIGIN OF THE HIGHER FUNGI.

MR. GEORGE MASSEE, the well-known mycologist of Kew, speculates (in Linn. Soc., *Jour. Bot.*, vol. xxxiv., p. 438) as to the origin of the group of fungi known as the Basidiomyceteae, which includes those genera generally regarded as the highest of the hysterophytes, viz, the puff-balls and their relatives, and the various forms of toadstools and mushrooms. Finding that the conidial fructification of certain Ascomyceteae bears some resemblance to the spore-bearing tissues of the Basidiomyceteae, he finds a series of more or less obvious gradations, and arrives at the conclusion that there is a genetic connection between them. According to this view some plants are Ascomyceteae as to their ascigerous, and Basidiomyceteae as to their conidial fructifications. While ingenious, it is not likely that this theory will be generally accepted.

SUPPLEMENT TO NICHOLSON'S DICTIONARY OF GARDENING.

STIMULATED, perhaps, by the publication of Bailey's 'Cyclopedia of American Horticulture,' the publisher of Nicholson's 'Dictionary of Gardening' (Gill, London) announces a '1900 Supplement' which is to appear in two volumes. The first of these supplementary volumes has come to hand, and fully justifies the statement of the publisher as to the quality of subject matter and mechanical execution. The illustrations are superb, in many cases being reproduced directly from photographs. Upon the appearance of the second volume a more extended notice will be made.

NEW EDITION OF PRANTL'S LEHRBUCH.

DR. PAX of Breslau has brought out the eleventh edition of the well-known 'Lehrbuch der Botanik' of the lamented Dr. Prantl, first

published in 1874, and much used some years ago in American colleges. It speaks well for the teachers of botany that this book has proved so popular as to have gone through so many editions, in spite of the fact that it has not departed essentially from the scientific sequence of topics, neither has it attempted to introduce popular 'natural history' features in place of the more difficult laboratory requirements. The book contains three 'parts,' the first of which deals with structural, the second with physiological, and the third with systematic botany. It may still be held up as a model worthy of being followed by makers of botanical text-books.

Charles E. Bessey.

The University of Nebraska.

THE COAL FIELDS OF CHINA.

Professor Drake, of Tien-tsin, has lately published a report on the coal fields in Shan-si province, which he visited last autumn, especially those around Tse-chau, which were first made known to the world by Baron von Richthofen in 1870, and for the working of which concessions have been granted to an Anglo-Italian company. According to the abstract in the London *Times*, the journey from the coast is made across low-lying plains, and then a plateau is ascended, on which the coal measures are found. The workable coal lies in one bed, about 250 feet above a flint-bearing limestone stratum, below which it is possible that there is also coal. In Tse-chau the average thickness of seam is probably not less than 22 feet, and at one place it is worked through a shaft 329 feet deep. Streaks of shaly coal are common in the part being mined, but there is no waste coal taken out, and the proportion of ash is little more than 10 per cent. There is no waste material in the bed in any of the mines. Professor Drake estimates that within the 150 square miles around Tse-chau there are about 3000 million metric tons of coal, and it "must be remembered that this area is only a little of the ragged edge of the great coal fields of Shan-si. Most of Shan-si has been found underlaid by large coal beds. Richthofen estimates that the anthracite coal alone of Shan-si amounts to 630,000 million tons, and that the coal area is greater than that of Pennsylvania." All the Tse-chau coal is anthracite, with a specific gravity of 1.5, and it is hard enough to support any weight put upon it in the blast furnace. The proportion of sulphur is uniformly low, and that of ash also. A cursory examination of the outcrops showed the iron ore stratum to be 2 feet to 3 feet in thickness; the workings are limited to this narrow strip because the ore beds lie near the surface and can be mined by open pits, whereas elsewhere deep shafts and long tunnels would be needed. But the small quantity of ore will probably never justify extensive mining at a depth. Besides coal and iron ore the district yields fire clays of good quality for bricks and cheap pottery. These are now much used by the Chinese for household utensils. Sandstone occurs in abundance and is extensively used by the Chinese; its fault is great friability. Massive limestones are in great abundance and of good quality. They vary in color from light gray to blue and almost black. The soil is largely *loess*, and is therefore fertile and highly cultivated, a dense population being supported by agriculture. The industries are centered round the mines. Nearly all the coal is mined through shafts varying in depth from 50 ft. to over 300 ft. Very little is mined through inclines. No steam is used for raising the coal to the surface, and explosives are not employed. The work is done with the windlass and pick. Tunnels are run through the bed from the bottom of the shaft, and at intervals along the tunnels large quantities of coal are removed, leaving circular chambers 40 ft. to 50 ft. in diameter, and thus about 50,000 tons a year are brought to the surface in the district. For local use, the coal is carried away in little carts drawn by oxen, but most of it is taken down the mountains by pack animals, as the paths are very steep and rough. It is 20 miles to the plains; the paths are about 13 ft. wide and are paved with stone. But "the great thickness and the almost horizontal position of this coal bed make it practicable, as suggested by Richthofen, for other Shan-si coal beds, to run long lines of railroad tunnels through the bed, and load the cars in the mines for distant transportation."

SCIENTIFIC NOTES AND NEWS.

THE British Association will meet next year at Glasgow, beginning on September 11th under the presidency of Professor A. W. Rücker. In 1902 the meeting will be at Belfast.

WE regret to learn that up to the present time, but 30 complete subscriptions have been received in the United States for the International Catologue of Scientific Literature. The successful beginning of the project is dependent upon at least 45 subscriptions from the United States, and it is necessary that these should all be in before the end of September. The Catalogue will comprise 17 volumes per annum, the subscription per annum is $85, and, in order to give the undertaking some sort of permanence, it is desired that these subscriptions shall be for five years. All subscriptions from the United States should be addressed to the Secretary of the Smithsonian Institution, Washington, D. C.

PROFESSOR H. T. TODD, having reached the age limit, has retired from the directorship of the Nautical Almanac. Professor S. J. Brown, astronomical director of the U. S. Naval Observatory, has untertaken the duties of the office.

Popular Astronomy quotes from the 'Navy Register' of 1900 the rank of all the mathematical officers in the navy on January 1, 1900. They are as follows: On the active list 'Rank of Captain': Professors Hendrickson, Todd and Oliver. 'Rank of Commander': Professors Brown, Rawson, Alger and Dodge. 'Rank of Lieutenant': Professors Paul, Skinner, See and Updegraff. On the retired list: 'Rank of Rear Admiral': William Harkness. 'Rank of Captain': Professors Newcomb, Hall and Eastman. 'Rank of Commander': Professors Frisby, Prudhomme and Rice.

PROFESSOR BALDWIN SPENCER has been given leave of absence from Melbourne University to study the ethnology of the natives of the northern part of South Australia.

M. FAYE, the eminent French astronomer, has been elected a foreign member of the Reale Accademia dei Lincei of Rome.

PROFESSOR E. A. SCHÄFFER has retired from the position of General Secretary of the British Association which he has held in conjunction with Sir William Roberts-Austin. Dr. D. H. Scott has been elected to the vacant place.

DR. J. M. DA COSTA, formerly professor of the theory and practice of medicine at the Jefferson Medical College, died near Philadelphia on September 11th. He was perhaps the most prominent physician in Philadelphia, and was the author of numerous contributions to pathology, his work on 'Medical Diagnosis' having passed through numerous editions and having been translated into several foreign languages.

MR. WM. SAUNDERS, the well-known horticulturist, died at Washington, on September 11th, in his 78th year. He had been connected with the U. S. Department of Agriculture since its organization in 1862. He was well-known as a landscape gardener, having planned Fairmount Park in Philadelphia, and done much similar work at Washington and elsewhere.

WE learn from *Popular Astronomy* of the death of Mr. David Flannery, of Memphis, Tenn. He was interested in astronomy and had made observations of variable stars.

ACCORDING to *Popular Astronomy* the will of Professor Piazzi Smyth makes provision for the publication of his spectroscopic manuscripts, and also for the assistance or promotion every ten or twenty years of an exceptional expedition for the study of some particular branch of astronomical spectroscopy at mountain elevations of not less than 6000 feet.

THE will of Mr. Charles H. Smith of Providence contains the following public bequests: $3000 to the Rhode Island Historical Society, $2000 to the Rhode Island Horticultural Society, $1000 to the city public schools for the purchase of microscopes, $3500 to Brown University, and real estate valued at upwards of $200,000 for the maintenance of the botanical specimens in the city park.

THOSE who have seen reference made to a forthcoming bulletin on the fishes of Porto Rico, to be issued by the U. S. Fish Commission, may not know that the publication has been delayed by a fire in New York, in which the drawings in black and white and such plates as had been engraved were destroyed.

The fine colored plates, however, being in the hands of another firm, were uninjured. Other drawings have been made to take the place of the more important of those destroyed and the work will be issued as soon as possible.

At the recent meeting of the British Association a committee was appointed to consider the following resolutions: "That in view of the opportunities of ethnographical inquiry which will be presented by the Indian census, the council of the Association be requested to urge the Government of India to make use of the census officers for the purposes enumerated below, and to place photographers at the service of the census officers: (1) to establish a survey of the jungle races, Bhils, Gonds, and other tribes of the central mountain districts; (2) to establish a further survey of the Naga, Kuki, and other cognate races of the Assam and Burmese frontiers; (3) to collect further information about the vagrant and criminal tribes, Haburas, Beriyas, Sansiyas, etc., in North and Central India; (4) to collect physical measurements, particularly of the various Dravidian tribes, in order to determine their origin; and of the Rajputs and Jats of Rajputana and the Eastern Punjab, to determine their relation with the Yu-echi and other Indo-Scythian races; (5) to furnish a series of photographs of typical specimens in the various races, of views of archaic industries, and of other facts interesting to ethnologists."

The great meteor of August 25th is reported to have fallen near Rangeley Lake, Me., exploding within a few feet of the hotel and disappearing, not a fragment having been discovered by a prolonged search.

The question of admitting women as members of the general and sectional committees of the British Association was brought up at the recent meeting and carried by a considerable majority.

We are glad to note articles in the New York *Evening Post* and the Boston *Evening Transcript* urging the importance of a bureau of standards. The item establishing the bureau submitted by Secretary Gage was generally favored by members of Congress and would doubtless have been passed had it not been for the wish to prevent a further increase in expenditures. If the measure is adequately discussed there is every reason to believe that it will be passed next winter.

A meeting of Government officials and meteorological and agricultural authorities is soon to take place at Hamburg, to discuss the introduction of a telegraphic service for German agriculture.

The *Windward* was expected to reach St. Johns at about the middle of the present month, but a short delay will not be surprising as it started late, owing to some difficulty with the machinery, and was subsequently delayed by ice along the coast of Labrador. The arrival of the steamship is awaited with interest and some anxiety as it will bring news not only of the return of Peary, but also of Captain Sverdrup and Dr. Stein. The former has the *Fram* provisioned for five years, with a crew of twelve men. He planned to round the northern boundary of Greenland and to make his way down its unknown east coast to Cape Bismarck. It is said that the expedition under Dr. Robert Stein of the U. S. Geological Survey, who is accompanied by Mr. Leopold Kann of Cornell University and Mr. Samuel Warmbath of Harvard University was poorly equipped and left in a dangerous position. Lieutenant Peary himself expected to establish his last depôt at Cape Hecla, the most northerly point of Grinnell Land just beyond the 82d parallel, whence he intended to advance with Eskimo and sleds as far north as possible.

It is reported in the daily papers that Captain Bernier, who has lately returned to Quebec from Newfoundland, states that when there he examined all the vessels engaged in the whaling business to select one for his proposed North Pole expedition. He says that none were considered by him strong enough to resist the pressure of the Polar ice. He has, therefore, proposed that the Canadian government build a suitable vessel out of the grant that has been promised. Captain Bernier says that his offers of assistance, exclusive of the government grant, now aggregate $25,000, and that the merchants of Quebec will donate supplies worth $6000 or $7000.

News has been received from the Liverpool

Expedition sent to Nigeria to the effect that all the members are perfectly well, although they have spent four months in districts where malaria is specially prevalent and deadly. They have not kept the fever off by the use of quinine, and they attribute their immunity to the careful use of mosquito nets at night. Experiments are reported in the *Archivio per le Scienze Mediche*, abstracted in the New York *Medical Record*, of an experiment carried out by Eugenio di Mattei on himself and four others. A hut situated in an extremely malarial region, infested by mosquitoes, was chosen, and here the five slept for thirty-two nights. Their work during the day was arduous, their food scanty, their accommodations were uncomfortable; they took no quinine or other medicament, but their hut was so completely protected by wire gauze that no mosquitoes were able to obtain access. No one of the five contracted malaria, although other workmen sleeping in the neighborhood and unprotected from the mosquitoes, suffered from grave forms of the disease.

In 1898 there was mined in the United States somewhat over nineteen million tons of iron ore, which was the largest quantity up to that time ever produced in a single country in a single year. But according to the announcement recently made by the U. S. Geological Survey, the production of iron ore in the United States was 24,683,173 tons, an increase of 27 per cent. over 1898. In spite of this large increase the price is about 25 per cent. higher than in 1898.

DR. REGINALD A. FESSENDEN writes as follows to the *Electrical World* referring to patents by Mr. Tesla which have been widely discussed in the daily press: "With reference to your article on 'Insulation by Freezing,' in the issue of August 25th, may I be permitted to point out that the patents referred to are invalid, as this method was fully described in my paper on 'Insulation and Conduction,' read before the American Institute of Electrical Engineers in 1898, and printed in its 'Transactions' (Trans. A. I. E. E., 1898, page 14). The passage is as follows: "The second (plan) occurred to the writer on reading Elihu Thompson's article on the use of liquid air as an insulator. It is this: Since ice at only 12 degrees below freezing has a specific resistance of over 1000 megohms, *i. e.*, as good as some brands of insulation, why not make the conductors hollow, lay them in a trench filled with water, pass cold brine through the pipes, use the brine for cooling houses, making ice, etc., and let the frozen water act as the insulator. A rough calculation shows that this is commercially feasible, even neglecting all sources of profit from the furnishing of the brine, *i. e.*, if it were used only for cooling the pipes. After making all allowance for friction of fluid, cost of power, etc., the balance comes at the right end, if the line is always fully loaded." This was published more than two years prior to the date of application of said patents, the said date being June 15, 1900.

THE report of the Principal Chemist of the Government Laboratory of Great Britain upon the work of the laboratory for the year ended March 31st last has been issued as a Parliamentary paper. According to an abstract in the London *Times* it appears that in the Customs Department during the past year, 226 samples of tea, representing 3322 packages, were found to contain exhausted leaves, or to be mixed with sand or other substances within the meaning of the Act, and were therefore refused admission for home consumption. Of these 3322 packages, 2274 were exported and 1048 destroyed. Eight thousand four hundred and eighteen samples of tobacco, tea, coffee, soaps, drugs, varnishes, etc., were examined during the 12 months; 167,080 samples of beer, spirits and wines were examined in the same period. The number of analyses and examinations made in the Excise branch amounted to 68,287, or 1864 more than in the preceding year. Seven thousand five hundred and two samples of wort in various stages of fermentation had been examined to check the declaration of gravity made by the brewer. In 614, or rather more than 8 per cent. of these cases, the original gravity was found one degree or more above that declared by the trader or found by the officer. In 583 cases the increased gravity was less than five degrees, in 26 cases five degrees and less than ten, and in five cases ten degrees and upwards. Two thousand three hundred and eighty-six

samples of finished beer taken from 1223 publicans were analyzed, and 319 or 13 per cent. of the samples were found to have been diluted with water or otherwise adulterated. Ninety-five samples of tobacco taken from manufacturers and dealers were analyzed for adulteration generally, and 20 of them were found to be adulterated with liquorice or glycerine. All the adulterated samples were apparently either smuggled cake cavendish or cut tobacco, which bore no label to show it had paid the proper rate of duty. While in 1841, when the population was 26,700,000, the quantity of tobacco cleared for consumption was 23,096,281 lb., or 13¾ oz. per head of the population, the quantity in 1900, with a population of 40,835,000, was 80,955,037 lb., or 1lb. 15¾ oz., per head. In the 'other Government Department's' branch the number of samples examined in connection with the Board of Agriculture had increased from 1600 in the year ended March 31, 1899, to 1745 during the last year. The increase was due partly to the new Food and Drugs Act. One thousand three hundred and ninety-three samples of imported butter were examined. Only six samples gave distinctly abnormal results. A large number of butters contained boric preservative and were artificially colored. As usual, it was found that the use of boric acid is most prevalent in France, Belgium, and Australia, and is very common also in Holland. The most frequent coloring-matter is annatto, but the use of coal-tar yellows appears to be on the increase, and is especially prevalent in Holland, the United States and Australia. One hundred and thirty-two samples of imported margarine were analyzed. The bulk of the margarine imported comes from Holland, and it is usually made with cottonseed oil, contains boric preservative, and is artificially colored with a coal-tar yellow. In all 1745 samples of butters, margarines, cheese, etc., were examined.

UNIVERSITY AND EDUCATIONAL NEWS.

Mr. Samuel Mather, of Cleveland, has offered to give Kenyon College at Gambier, Ohio, $10,000 for every $15,000 secured from other sources. This has resulted in a gift of $15,000 from Mr. J. P. Stevens for a library fund.

With the opening of the scholastic year this month the Christian Brothers in their colleges in the United States enter upon the new order prescribed for them by their superiors in France, who have decided that hereafter modern languages shall replace the classics. Manhattan College, New York, and others of the best Catholic Colleges giving the B.A. degree must follow these directions, though it is said that they may cause a division in the Order.

The Congress of British Chambers of Paris' which met at Paris this month adopted the following resolution: "That this meeting endorses the following resolution, which was adopted at the Congress of Chambers of Commerce of the Empire in June, 1900: 'That it is most desirable to take steps to urge the extension of technical and commercial education throughout the Empire, and that wherever possible this education should be placed under efficient public control; and that this Congress is of opinion that the utmost effort should be made throughout the Empire to encourage and furnish facilities for commercial education as a branch of technical and scientific study, and that the Home and Colonial Governments be moved to give aid thereto and ample powers of contribution out of local resources; and, further, it is very desirable that Chambers of Commerce should be represented on Boards of Education in order to advance the interests of commercial education.'"

Dr. Oustalet, assistant in the Paris Natural History Museum, has been made professor of zoology (mammals and birds) in the Museum in succession to the late M. Milne-Edwards.

Professor Craig of the Ames Agricultural College and formerly horticulturist of the Dominion Experiment Farm at Ottawa has been called to Cornell University for work in horticulture.

Professor Wendell Paddock of the Geneva Experiment Station has been elected professor of horticulture in the Colorado Agricultural College.

Professor Percy J. Parrot of the Kansas Agricultural College has been appointed entomologist at the Geneva Experiment Station.